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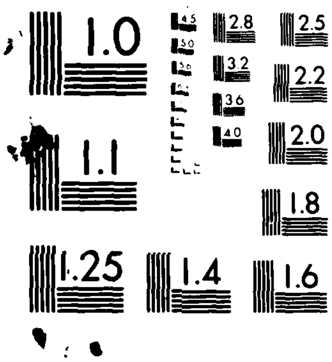

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COMMENCEMENT BAY STUDY

Physical Oceanography

prepared by

Dames & Moore

for

U.S. Army Corps of Engineers, Seattle District

Volume VI

December 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In the 20-month period ending December 1981, Dames & Moore (Seattle) assisted by four subcontractors completed a Phase I effort to collect baseline data and provide a detailed description of the natural and human systems of the Commencement Bay area in the southern Main Basin of Puget Sound in Washington State.

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Data, interpretations, and conclusions in this report are those of the authors.

COMMENCEMENT BAY STUDIES
TECHNICAL REPORT

VOLUME VI

PHYSICAL OCEANOGRAPHY

for

U.S. Army Corps of Engineers
Seattle District

December 1981

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ACKNOWLEDGEMENTS

Dames & Moore and Northwest Consultant Oceanographers, Inc. wish to thank the following persons who have contributed to the physical oceanographic portion of this report. David English participated in the field program and helped in the reduction of the data and preparation of many of the illustrations. Peter Harris assisted in reducing the data. Rachel Johnson ran the computer, prepared most of the computer plots, and assisted in the data reduction. Jan Loehr and Gail Sullivan participated in the field programs. Gail also typed the original manuscript. David Haury prepared the sections on wave analysis and flushing times.

In addition we wish to thank the Corps of Engineers for supplying the RV SEIGLEY for use in the winter study. Without the use of this larger boat and its very competent operator, Art Hoverson, the winter study in Commencement Bay would not have been successful. During the summer study, the use of a privately owned boat operated by Guy Manning of Tacoma was very much appreciated. The intensive winter waterway study also involved a privately owned boat leased from Gordon Pickering of Tacoma.

LINCOLN C. LOEHR
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December 1981

1.0 INTRODUCTION

1.1 GENERAL

Dames & Moore contracted with Northwest Consultant Oceanographers, Inc. (NCO) to study the circulation patterns in Commencement Bay and the associated industrial waterways during summer low river flow conditions as part of the Corps of Engineers (Corps) Commencement Bay Studies (COBS). Under a modification to this contract, NCO performed a similar study during winter high river flow conditions. This latter effort included a report of the summer bay studies and a more intensive study of Blair Waterway, but no investigation of the other waterways.

The specific objectives of these studies, as outlined in Section 3.8 of the Statement of Work (Corps of Engineers, Seattle District) are as follows:

a. Determine flushing characteristics in the waterways (Section 2.0 and 3.0),

b. Determine circulation/current patterns in Commencement Bay (Section 4.0),

c. Identify and describe the wave patterns along the exposed shorelines (Section 5.0).

The studies conducted are described in Sections 2.0 (Field Studies - Waterways), 3.0 (Water Replacement - Waterways), 4.0 (Field Studies - Commencement Bay), and 5.0 (Wave Analysis). These sections present the methods used and results obtained in each of the physical oceanographic studies undertaken in the bay and waterways. Conclusions derived from these studies are presented in Section 1.2.

1.2 STUDY CONCLUSIONS

1.2.1 Waterway Studies

A general pattern of circulation within the waterways emerged from the summer and winter drogue studies described in Section 2.0. There is a net inflow below 6 m and a net outflow at 2 to 6 m. The surface also displays a net inflow, although winds from the southeast can reverse this. The base of the pycnocline (depth range over which a rapid change in density occurs) was defined in the winter study by the 28 ppt salinity isosal at 3 to 4 m. Because circulation at 2 to 4 m behaved similarly in the winter and summer studies, we assume that the pycnocline would be similar in the summer, although no detailed density profile was available for that period. Specific conclusions are:

1. The surface flow (0.1 to 0.5 m) in the waterways and in Commencement Bay is strongly influenced by winds. Amplifying or retarding of this surface flow by the wind results in considerable shear. A pollutant distributed evenly over the upper meter would be rapidly dispersed over a large area because of this shear.

2. Strong flood flows, if not opposed by the winds, will replace the upper 1 to 2 meters of the entire waterway with surface water from Commencement Bay. The original surface waters must be displaced downward to accommodate this input.

3. The plume of the Puyallup River usually does not reach the southern pocket of the bay, so the surface waters of City Waterway are more saline than the other waterways. Consequently, the circulation patterns within City Waterway do not fit the pattern of the other waterways because the density structure of the water column is different. The surface waters of City Waterway are less turbid and more saline than the surface waters of the other waterways.

4. The surface reversals are often in response to changes in the wind rather than the tide. Other depths reverse with considerable "lag" or "lead" on the high and low tide conditions. Reversals occurred rapidly in the shorter waterways and were evident in both inner and outer segments for the same depths in the same time frame. The longer waterways (Hylebos and Blair) did not display such simultaneous reversals, often exhibiting contrary flows at the same depth in different segments of the waterways.

5. The water at 3 m often showed resistance to flood flow. The behavior of the drogues at 3 m influenced the design of the winter study which then determined that the base of the pycnocline was at 3 m.

6. The currents respond to cross-channel winds.

7. Cross-channel flow frequently occurs, indicating that the ebb and flood flows may meander from side to side and localized eddies may occur.

8. Flows are generally faster in outer regions than in inner segments. However, the surface flow, which was wind influenced, was sometimes greater in the inner segments.

9. The winter and summer studies of Blair produced comparable results, supporting the assumption that the tide and not the Puyallup River flow was the most significant driving force. The winds appear to be more significant than the Puyallup River in affecting the circulation.

10. The determination of the density distribution on consecutive tides provides an excellent means of assessing the circulation and assisted in interpretating the drogue data.

11. From experience the authors have had with physical and mathematical models, it is doubtful that either type of modeling

effort could reproduce the circulation patterns observed in the field experiments.

1.2.2 Water Replacement - Waterways

A commonly expressed environmental concern is "what is the residence time of a pollutant discharged into the waterway?" Factors to be considered in answering such a question include (but are not limited to): (1) the density of the pollutant; (2) location of discharge; (3) whether the pollutant remains in solution or settles out by some mechanism; (4) whether the pollutant is chemically stable or whether it changes or breaks down, and if so, the rate of change; (5) whether the pollutant is removed from or transported by biological processes; and (6) the pertinent physical and chemical processes and characteristics of the waterway. It should be noted that not all of these factors affecting the residence time of a pollutant necessarily affect the residence time of a given parcel of water.

The concept of residence time is often misunderstood or misapplied. Flushing characteristics as described in Section 3 are based solely on intertidal volume exchange computations. Other factors such as density differences, changes in barometric pressure, runoff, precipitation, winds, and other processes significantly affect replacement time. Given the assumptions of the intertidal volume exchange methods of Section 3, residence times are directly proportional to the water depth, a shallower waterway having a shorter residence time. The replacement of water in Blair Waterway from the intertidal exchange computations in Section 3 varied from 3 to 15 days, depending on the degree of mixing of incoming water that was assumed.

Given what is now known concerning currents in the waterway, and how little is known about the variables affecting various pollutants, it is not feasible to physically or mathematically model these systems to reasonably assess the first question of this section.

1.2.3 Bay Studies

The current studies in Commencement Bay were designed to provide an overview of circulation patterns within the bay during summer and winter conditions. One objective was to evaluate the effects of low- and high-river flow on the surface circulaton of marine waters in the COBS study area. Unfortunately, nature did not cooperate, and the river flow was not much greater in the winter than in the summer study (see Table 1). The surface currents did not show significant differences between the seasonal studies.

Tide model studies reported by Brown and Caldwell (1957) indicated a counterclockwise flow in Commencement Bay on the rising tide. Direct observations of the same model by NCO personnel also indicated counterclockwise flow in the bay (Lincoln 1979). During the summer studies, a weak counterclockwise trend at 20 m was observed, but a stronger clockwise flow from the surface to 10 m existed. The winter study also indicated a clockwise flow, although less pronounced than in the summer study. No counterclockwise flow was noted during the winter study. It is interesting to note that the clockwise flow indicated in both seasonal studies is partially reflected by the movement of salmon drift nets used by the Puyallup Nation locally.

Currents in the southern pocket of the bay off City Waterway are often weak and variable at all depths. Many studies have indicated that the plume of the Puyallup River seldom enters City Waterway. It is hypothesized that the Puyallup River generates a weak back eddy in this southern pocket.

Water along the Ruston shoreline has a relatively short residence time in Commencement Bay because there is a net transport to the northwest toward Point Defiance. Within the inner bay (east of a line extending approximately from Browns Point to Commencement Park at Old Tacoma),* the

*The arbitrary boundary used to define the inner bay should not be construed as a firm boundary between distinctly different systems. Rather, there is a gradation from one to the other which varies in location with time, tide, river, wind, and depth.

TABLE 1. Puyallup River flow (cfs)
for August and September 1980 and February 1981

Day	AUG	SEP	FEB
1	2190	2010	2300
2	2280	5800	2050
3	2280	3660	2370
4	2170	2570	1450
5	1920	2230	1420
6	1640	2080	1690
7	1640	1780	1900
8	1740	1840	1060
9	1770	1880c	1960c
10	1860	1890c	1590c
11	1900	1600	1880c
12	2010	1700	6290c
13	2100	1480	8150
14	2080	1740	7540
15	2030	1500	7400
16	1980	1850	11100
17	1960	1570	12900b
18	2080w	1660	11400b
19	1960w	1290	13800
20	1890	1980	12600
21	1430	1980	8470
22	1330	1830	6350
23	1680	1450	5390
24	1550	1310	4890
25	1420	1460	4640
26	1490	1370	4100
27	1710w	1350	3820
28	2170w	1480	3580
29	1230w	1220	
30	1500	2070	
31	2070		

w = Waterway Studies

c = Commencement Bay Studies

b = Blair Waterway Intensive Study

Source: United States Geological Survey, unpublished data.

water at and below 5 m shifts directions with the tide, exhibits very little net movement, and hence, has a long residence time. The surface flows are strongly influenced by the Puyallup River and the wind, and they generally exit the inner bay in less than a day. Some surface water of the bay does enter the waterways with tide and wind where it is retained longer.

1.2.4 Wave Analysis

A wave analysis applicable to the Ruston and Old Tacoma shoreline was conducted using 2 years of hourly wind data from a nearby station and extreme wind data from Sea-Tac Airport. The extreme waves were computed to have significant wave heights of about 5 feet. However, 98 percent of the time the computed wave height was less than 1 foot.

2.0 FIELD STUDIES - WATERWAYS

2.1 INTRODUCTION

Figure 1 presents the Tacoma Harbor and waterways. The waterways are natural features that have been drastically modified by dredging and filling projects on the delta of the Puyallup River (see the Land and Water Use Technical Report). The surface waters of these waterways are diluted mostly by the plume of the Puyallup River. Fresh water from the river enters from the mouth of each waterway, as opposed to most estuaries where the freshwater input is from the head. There are no other areas in Oregon or Washington where the major freshwater input is from the seaward end. Thus, the waterways of Tacoma are unique.

No previous circulation studies are known to have been conducted within the waterways. Brown and Caldwell (1957) attempted to use aerial photography to evaluate surface currents in Commencement Bay; however, cloud cover and haze hampered their effort. As part of these studies, flights were made several times a day on May 28, June 21, and July 20, 1956, the main purpose being to observe the Puyallup plume in open water areas of the bay. Data from the aerial photography study were not sufficiently detailed to permit analysis of surface circulation within the waterways. Salinity studies of the surface water conducted as part of the Brown and Caldwell report indicated the tremendous influence of the Puyallup River plume on the surface waters of the waterways, depending on local wind conditions and tide stage. Black and white aerial photographs taken on July 25, 1978 by the Corps of Engineers clearly showed Puyallup River water (identified by the turbidity) within the waterways, but it was not possible to determine velocities of the surface water as the photographs did not represent a time series.

The physical oceanography summer field program was designed to study currents in the waterways for conditions of small tide ranges (neap tides) and large tide ranges (spring tides). The neap tide study was conducted during daylight hours on August 18-19, 1980 for rising tides of about 7 feet and falling tides of about 3 feet. Puyallup River flow data

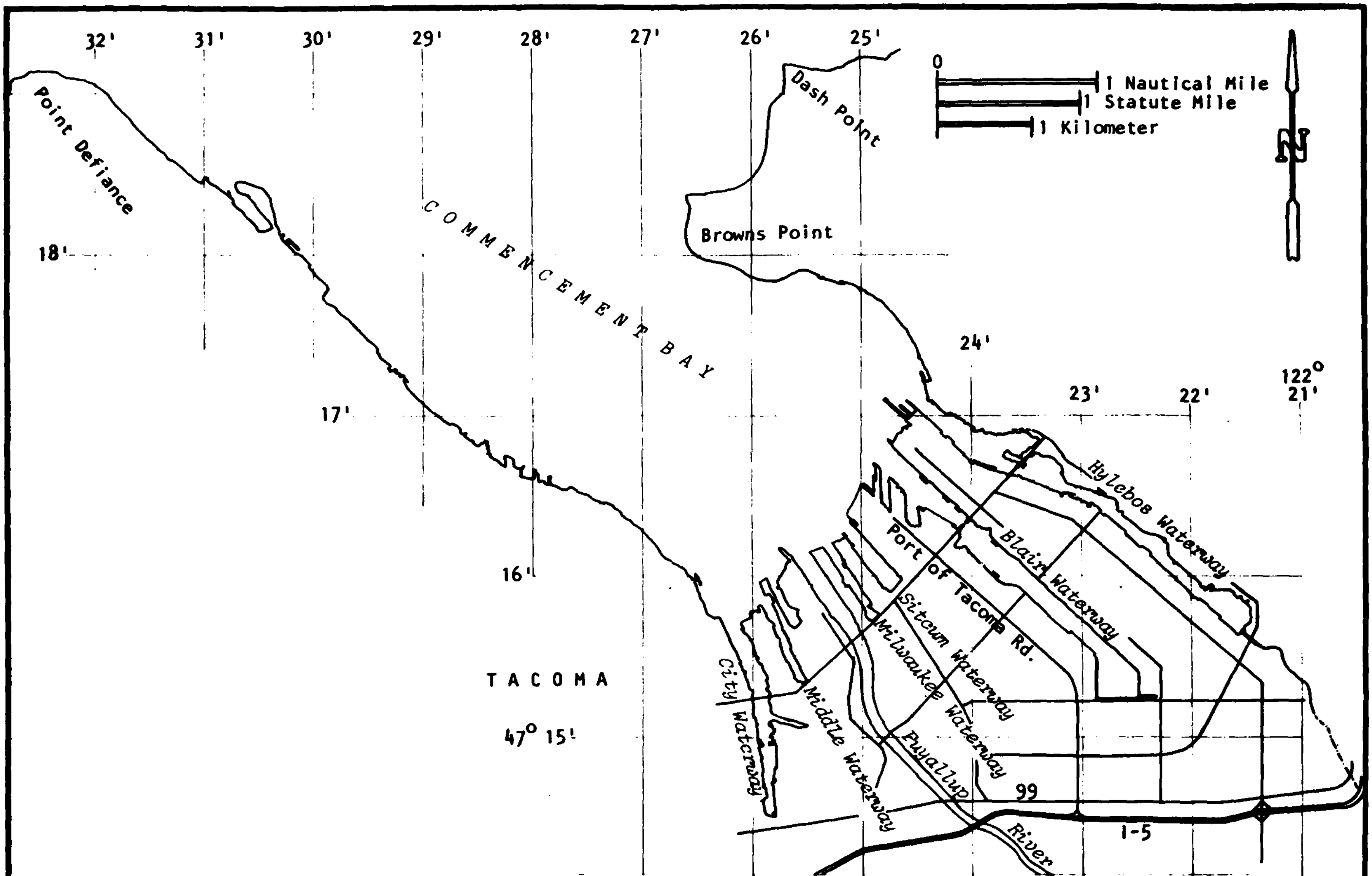

Figure 1

COMMENCEMENT BAY AND THE WATERWAYS OF TACOMA for the entire study period are presented in Table 1. River flows on these days averaged 2,000 cfs.

The COBS spring tide study was conducted on August 27-29, 1980 and covered rising tides of about 13 feet and falling tides of about 9 feet during the daylight hours. River flows were similar to the neap tide studies.

The winter study, conducted on February 17-18, 1981, concentrated on Blair Waterway. Tide ranges sampled varied from 4.7 to 13.7 feet on the rising tides and 7.1 to 11.9 feet on the falling tides. River flows were greater than 11,000 cfs, well above the winter average of about 5,000 cfs.

2.2 METHODS

Drogues were released at selected sites and depths within the waterways and were tracked by personnel on a small boat. Drogue positions were estimated from charts with a superimposed grid drawn to a scale of 1:2,400. Separation between grid coordinates equalled 20 feet in the prototype. Estimated positions were within 60 feet or less, depending upon the location within a waterway (i.e., availability of distinctive reference points, width of waterway).

Drogues were of two designs (see Figure 2). Shallow currents (0.1 m to 0.5 m) were followed with small cross-vane drogues approximately 0.1 m in height and with 0.05-m^2 surface area exposed to the current. The cross vanes were attached by a wooden dowel 1.2 m long to a plywood surface float with minimal wind resistance and less than 1 cm freeboard. A small, colored pennant at the top of the dowel increased the drogue's visibility.

Currents at or below 1 m were followed with windowshade drogues of approximately 1-m^2 surface area attached to a surface float of styrofoam. Laboratory tests (Vachon 1973) indicated the windowshade design offers the greatest drag coefficient, and hence, has the best "hold" on

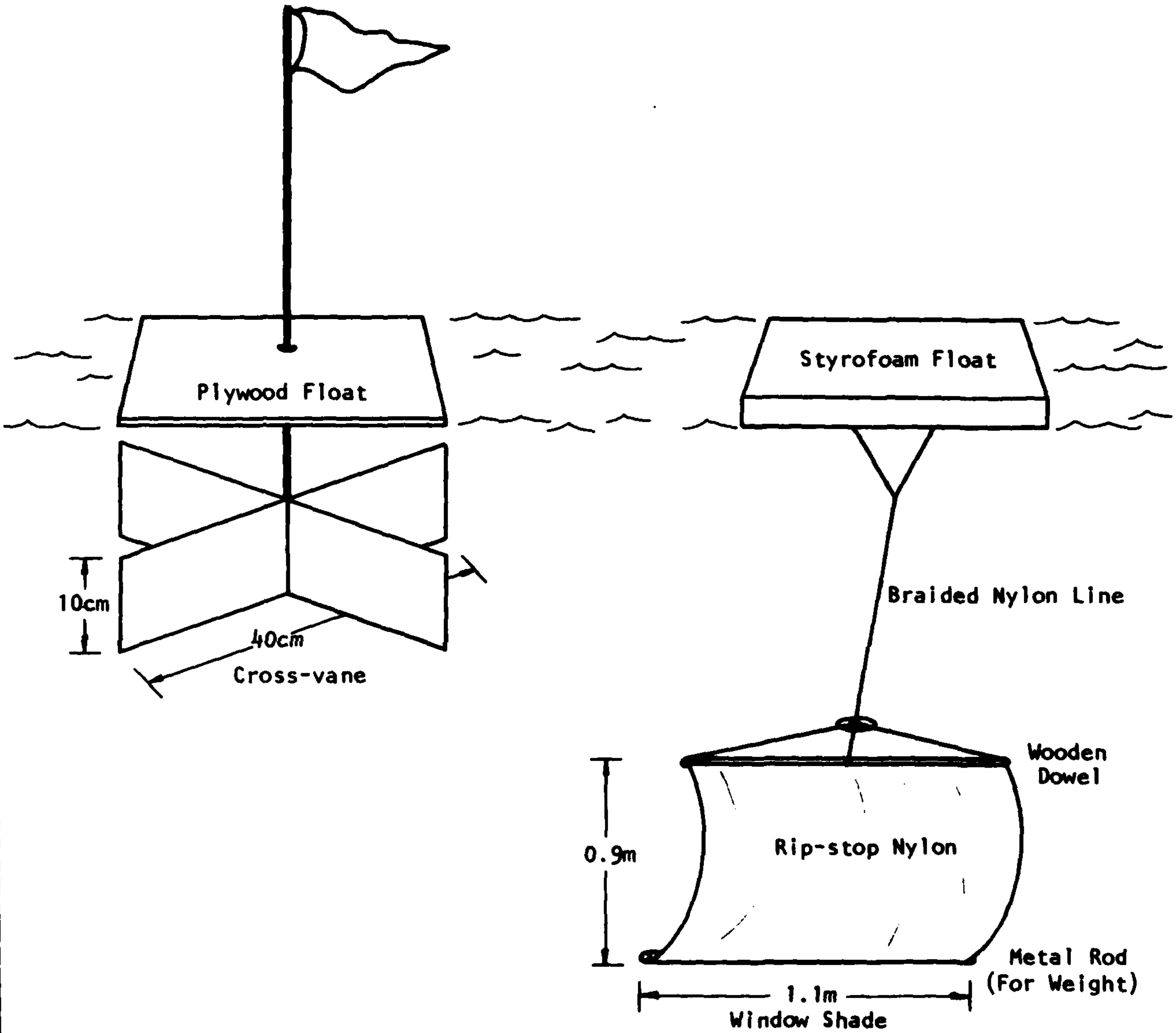

Figure 2
DROGUES USED IN STUDY

job no. ______ drawn by ______ date ______ checked by ______ the water. NCO has compared this design with parachute drogues of about 1 m diameter in earlier field studies in the open waters of Commencement Bay (Parametrix 1979) and in Port Susan, Washington (NCO 1978) and has found that both shapes behaved the same.

The windowshade drogue samples a 1-m segment of the water column. Therefore, when the windowshade drogue is set at 1 m, its movement in fact represents the average of the currents between 0.5 and 1.5 m. The shallow cross-vane drogues were designed to examine flows in finer increments of the water column. Collias and Loehr (1974) utilized similar drogues in southern Hood Canal and observed considerable shear in the upper meter. Current meter measurements by NCO (Parametrix 1979) in Commencement Bay near the mouth of the Puyallup River indicated considerable shear associated with the Puyallup River plume during low river flow conditions when the plume was a very shallow feature in the bay. Such surface shear is usually not evaluated in Lagrangian (drogue) or Eularian (current meter) studies but is important to the circulation and flushing dynamics of most harbor areas, particularly for evaluating the distribution of a pollutant within the surface waters.

Typical depths at which drogues were deployed in the waterways during the summer studies were 0.1 m, 0.5 m, 1 m, 3 m below the surface, and 3 m above the bottom of the channel. For Middle and Milwaukee Waterways, single point, multiple depth launches were used, treating each of these small waterways as a whole. City and Sitcum Waterways were divided into inner and outer segments, with two launch points used for a given tide condition. The largest waterways, Blair and Hylebos, were divided into outer, middle, and inner segments. Three launch points were used to characterize the circulation.

As previously mentioned, the winter study focused on Blair Waterway and was considerably more detailed than the summer study of the same area. Currents were measured by drogues and by current meters from a vessel moored in the middle segment of the waterway. Conductivity, salinity, temperature, and depth (CSTD) recordings were made to evaluate the effects of freshwater flow (mostly from the Puyallup River) and to identify significant features of water masses at different depths. The winter sampling involved 3 boats and 7 people and ran for 30 consecutive hours. Nighttime fieldwork was required to take advantage of the largest tide ranges at this time of the year.

During the winter study, the depths sampled by drogues were expanded to 0.1 m, 0.5 m, 1 m, 2 m, 3 m, 4 m, 6 m, and 10 m. Launches and recoveries were conducted on the first and last halves of each rising or falling tide.

Data analyses were performed both manually and by computer. Fix information was keypunched, proofed, sorted, and converted from the grid system to latitude and longitude by computer. Drogue trajectories were computer-plotted, and faulty fix points were identified from the plot and resolved (keypunch errors, initial fix error, recording error, etc.). Plots were computer-generated for the corrected data and tables computed to indicate drogue speeds and directions between fixes, total distance traveled, total running time, and average speed for the total run of the drogue.

Drogue trajectories in Blair Waterway for the winter study were hand plotted during the fieldwork, eliminating the need for computer plotting. Computer tabulations for the winter study were performed. Current meter data were averaged for the same time periods during which drogues were deployed in the middle segment. The CSTD data were used to plot isosals (lines of equal salinity) in Blair Waterway which were compared to the movement of water as identified by the drogues and current meters. The tables, plots, and salinity profiles formed the basis for further analysis.

All the computed velocities were converted to their components of motion along the channel axis for each waterway. The longitudinal speeds obtained were hand plotted, relating the flows at different depths and segments of a waterway to other depths and segments. These plots were made for each segment for the first and last halves of the rising and falling tides for "spring" and "neap" tides. To aid in visualizing the movement of water into and out of the waterways, current profiles were constructed from the derived longitudinal speeds. Gaps occur in the figures prepared for the summer study because the final method of presentation was determined after the fieldwork was conducted. The winter study was more tailored to this type of presentation. These current profiles present a time-weighted, average speed in or out of the waterway based on all the drogues within a given segment, depth, and time frame. Cross-channel flow is eliminated from this two-dimensional approach. Similar profiles were constructed from the current meter data in the winter study.

2.3 SUMMER STUDY RESULTS

Drogue trajectories and tabulations of locations and velocities between fixes for the summer study are available through the Corps of Engineers, Seattle District, as an unpublished appendix to this report. Some trajectories are presented herein to illustrate features of interest. Current profiles are presented in this report as our interpretation of the circulation from the numerous trajectories. Our emphasis on the net inflow or outflow reduces the waterways to a two-dimensional system (length and depth). The longitudinal plots for each waterway represent a summary of observations covering an entire day of observations, 5 to 10 computer plots and 10 to 20 pages of tables. Frequent cross-channel and eddy flow at all depths was observed. Each waterway will be discussed separately.

2.3.1 Hylebos Waterway

Neap Tides - August 19, 1980

Figure 3 presents current profiles and average longitudinal speeds obtained for the inner, middle, and outer segments of Hylebos Waterway for August 19, 1980. Work in Hylebos Waterway was hampered by frequent movements of merchant vessels and tugs with large log rafts.

Flooding currents in the upper half meter were the strongest throughout the waterway, with longitudinal speeds of 0.5 knot (kt) observed. The surface continued to floo' on the falling tide as well and appeared to be driven by local winds that blew toward the waterway from Commencement Bay.

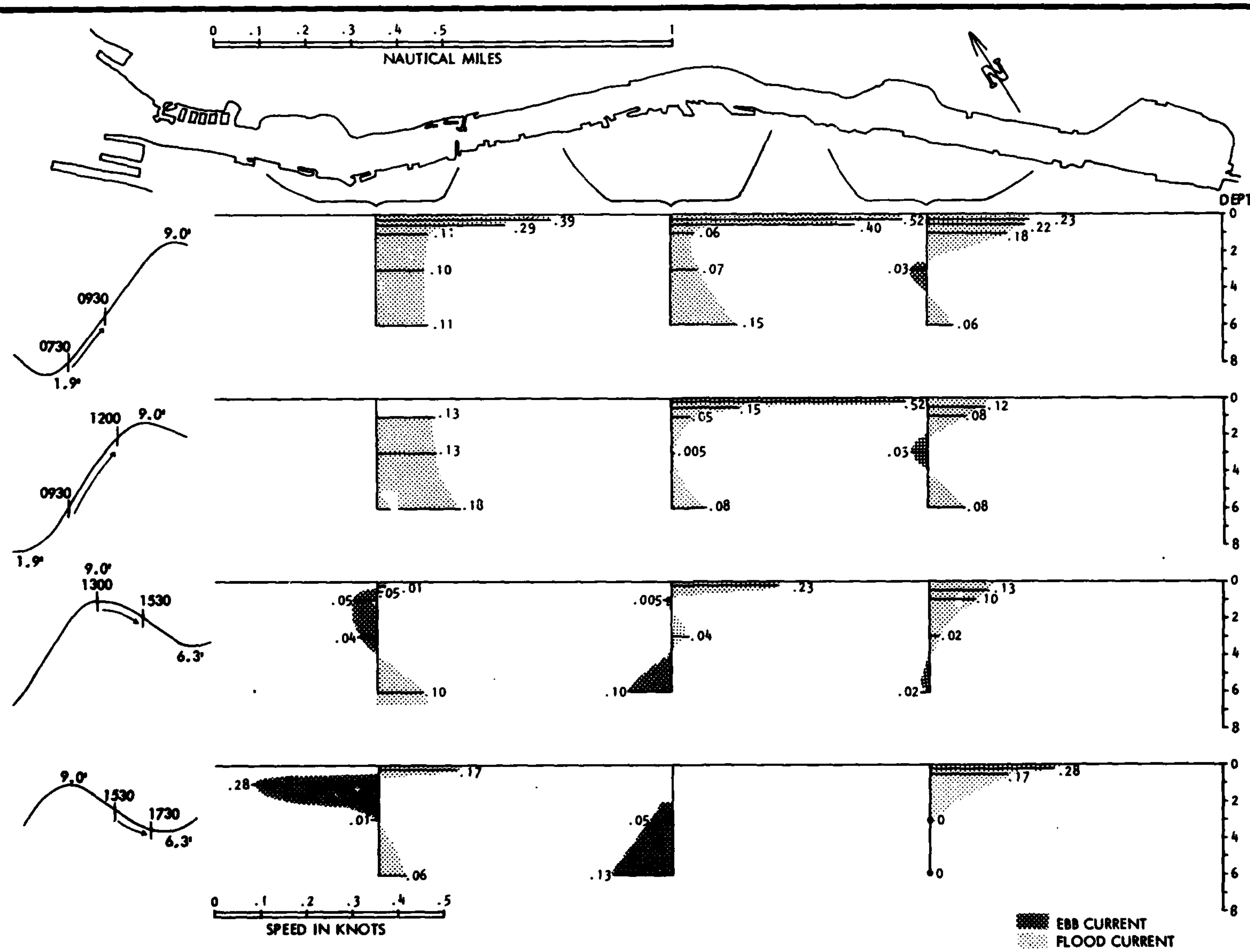

Figure 3
HYLEBOS WATERWAY
CURRENT PROFILES
19 AUGUST 1980

The flow at 0.5 m in the inner segment flooded during both rising and falling tides, while in the outer segment flood flow occurred only during the rising tide. Cross-channel flow dominated at this depth for the falling tide.

At 1 m, flooding occurred for all segments on the rising tide, and continued during the falling tide in the inner segment. A strong ebb current at 1 m in the outer segment was observed on the falling tide, with a longitudinal speed of 0.3 kt in the last half of the falling tide.

The water at 3 m behaved erratically, often exhibiting cross-channel flow, meandering motion, or even flow contrary to the ebb or flood expected during falling or rising tides. On the rising tide, 3 m flow was flooding in the outer segment, and consistently (but weakly [0.03 kt]) ebbing in the inner segment. During the small falling tide, the current at 3 m was weak and either cross-channel or meandering. The flow was weakly out in the outer segment, weakly in in the inner segment, and changed from in to out in the middle segment during the falling tide.

The flow at 6 m was flooding consistently in all segments on the rising tide at 0.06 to 0.18 kt. On the falling tide, the inner segment was essentially motionless at 6 m. Water in the middle segment was slowly ebbing while water in the outer segment continued to flood with a longitudinal speed of 0.06 to 0.1 kt opposing the 6 m flow of the middle segment.

Figure 4 presents drogue trajectories for a launch on the falling tide near the bend in the channel of outer Hylebos Waterway. These data are presented to show how radically the water column behaved. From launch at 1550 to the next observations 35 minutes later, the water moved as follows:

Depth (m)	Speed (kt)	Direction (°T)
0.1	0.17	149
1.0	0.07	304
3.0	0.06	031
6.0	0.11	117

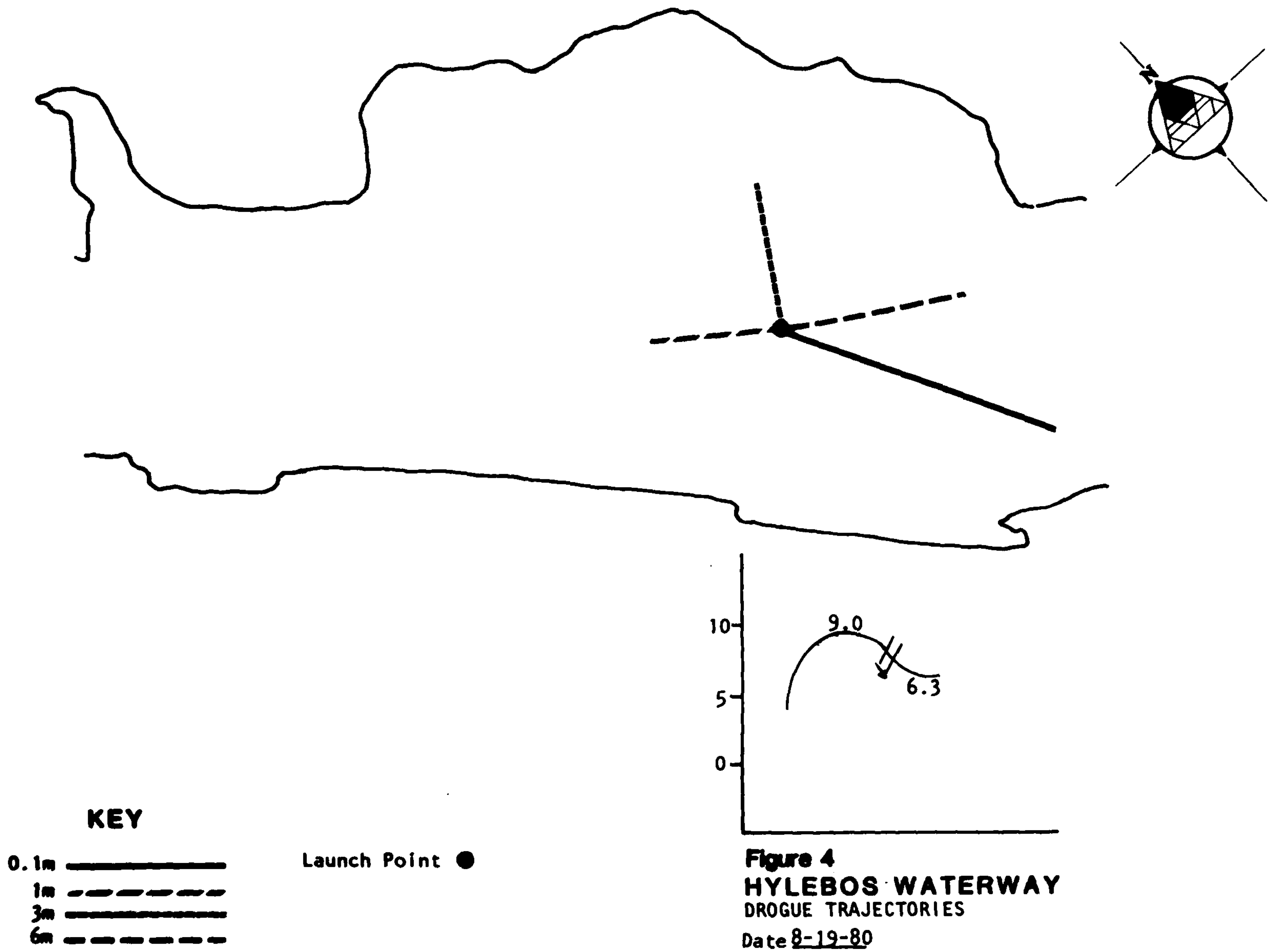

Figure 4
HYLEBOS WATERWAY
DROGUE TRAJECTORIES
Date 8-19-80
Start Time 1550 Recovery Time 1625

An object slowing sinking through the water at this time would have spiraled clockwise through 328 degrees.

Spring Tides - August 28, 1980

Figure 5 presents current profiles and average longitudinal speeds obtained for the inner, middle, and outer segments of Hylebos Waterway for August 28, 1980. Compared to the neap tide studies, the flows observed were stronger and reverse flow (in opposition to the rise or fall of the tide) was not evident. The entire water column ebbed on the falling tide and flooded on the rising tide.

The 0.1-m and 0.5-m flow was strongest on the rising tide, while on the falling tide it was deflected toward the shore and appeared to weakly ebb, indicating wind effects. Water at 6 m showed a resistance to the ebb flow at the outer segment, moving seaward with a speed of 0.01 kt. As on the neap tide study, movements of tugs and tows hampered data collection, leaving gaps in the current profiles.

Comparison of the spring tide current profiles with neap tide profiles indicated that a portion of the water column from 1- to 3-m depth shows a resistance to flood flow throughout the waterway while flood flow was strong at 6 m and at the surface. The surface flow was enhanced by the wind which was blowing from Commencement Bay toward Hylebos Waterway at 5 to 10 kt on August 19 and about 5 to 15 kt on August 28. Winds within the waterway were more subdued, generaly less than 5 kt.

2.3.2 Blair Waterway

Neap Tides - August 19, 1980

Figure 6 presents current profiles and average longitudinal speeds obtained for the inner, middle, and outer segments of Blair Waterway for August 19, 1980.

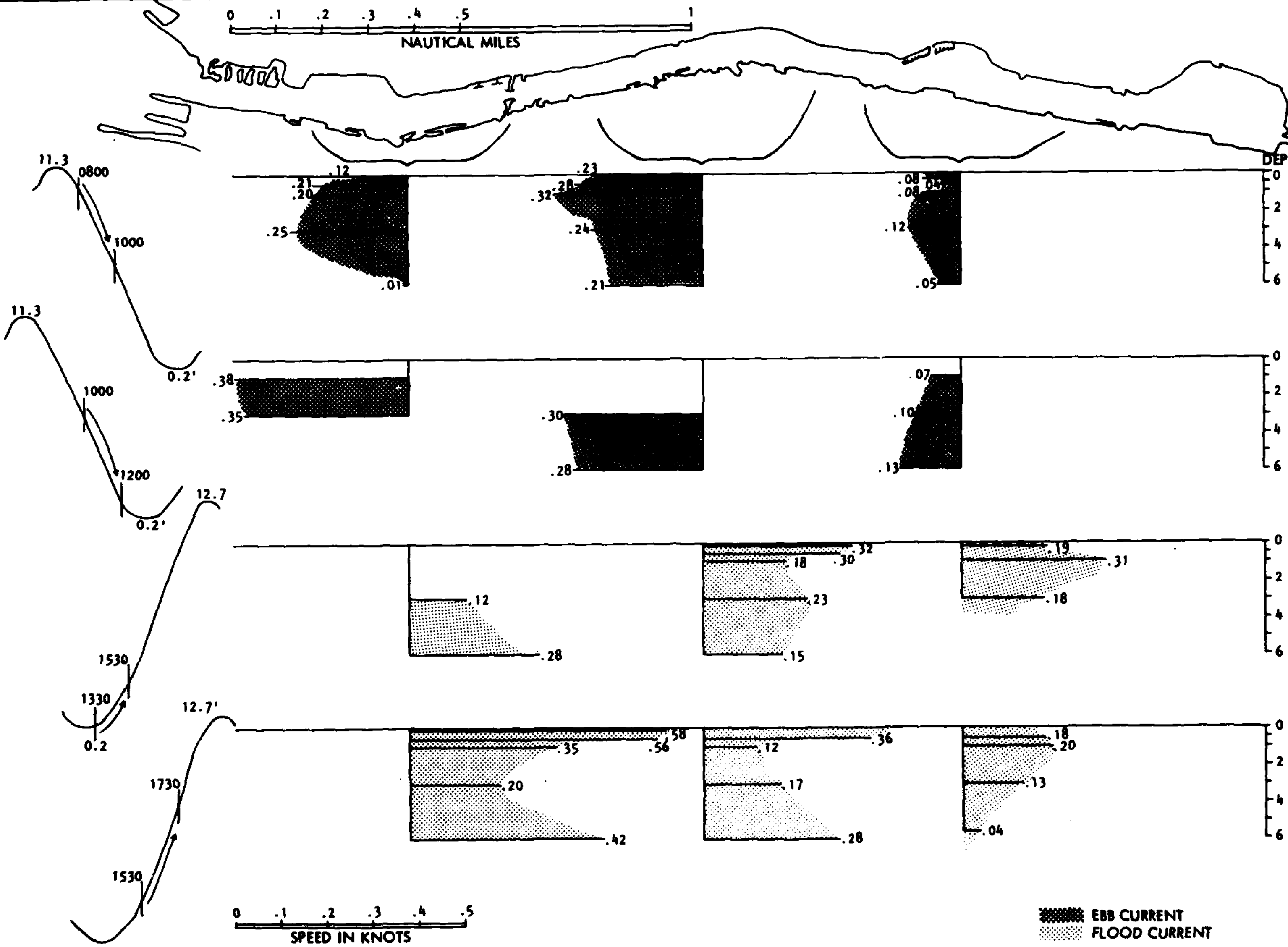

Figure 5
HYLEBOS WATERWAY
CURRENT PROFILES
28 AUGUST 1980

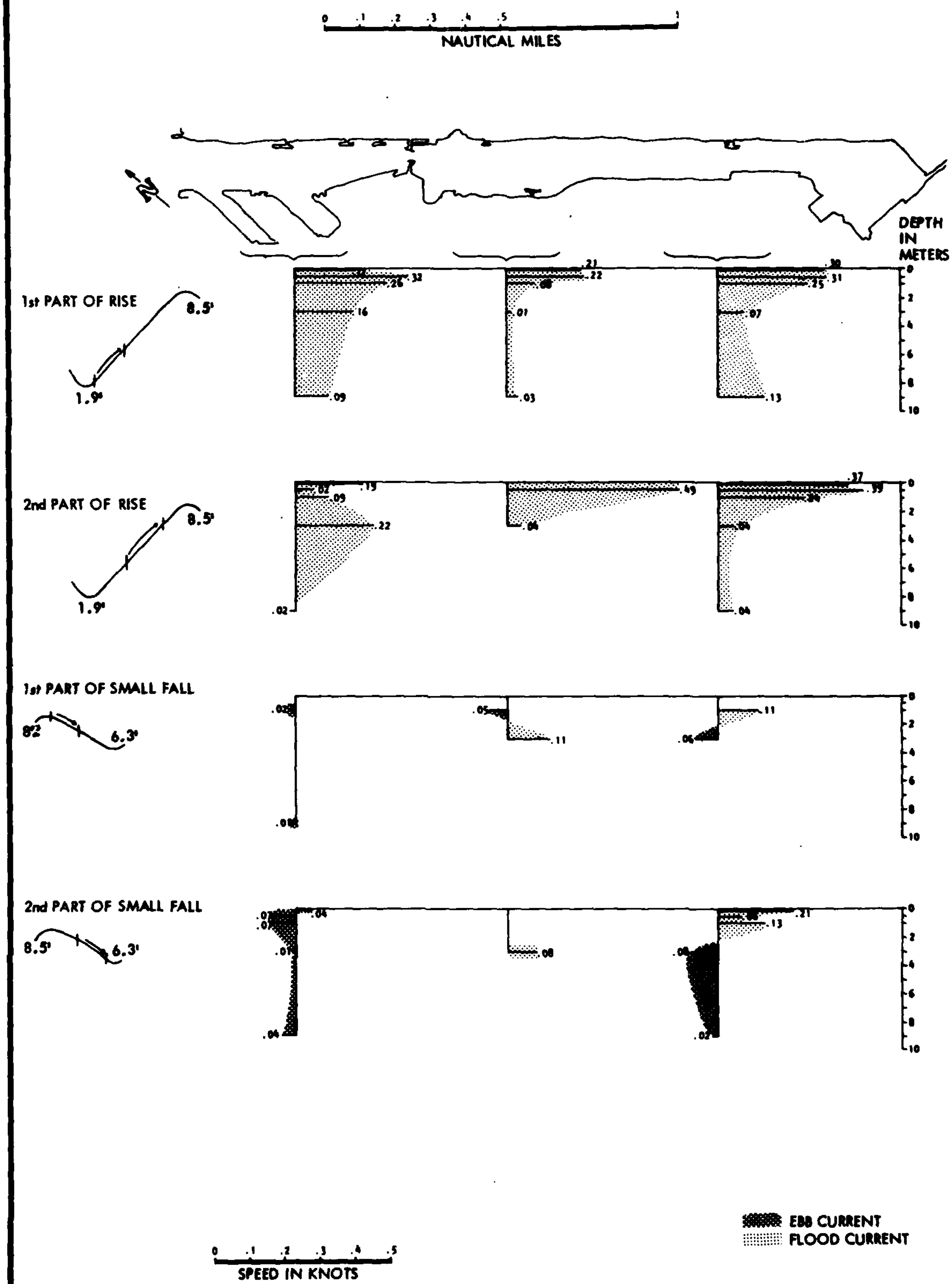

Figure 6
BLAIR WATERWAY
CURRENT PROFILES
19 AUGUST 1980

Water at 0.1 m flooded strongly (0.17 to 0.37 kt) with the rising tide and continued to weakly flood (0.04 to 0.21 kt) on the small falling tide. This behavior was similar to that of Hylebos Waterway for the same day. The surface flood flow, even on the small falling tide, was attributed to the surface winds within the waterway and within Commencement Bay.

On the rising tide, water at 0.5 m was flooding strongly in all segments while both weak ebb and flood flows occurred on the falling tide. The 1-m flow generally followed the 0.5-m flow, although weaker. The 3-m flow showed a resistance to flood flow in the middle and inner segment on the rising tide, with longitudinal speeds ranging from 0.01 to 0.07 kt. The outer segment on the rising tide experienced flood flow at 3 m of 0.16 to 0.22 kt.

On the small falling tide, ebb flow was well pronounced in the inner segment at 3 m, while flood flow existed for the same depth in the middle segment. Sluggish ebb flow was evident on the last half of the falling tide for the outer segment. The flow at 9 m was primarily flooding in all segments on the rising tide (0.03 to 0.3 kt), although water in the outer segment reversed direction between the first and second half of the rising tide. Weak ebb flow existed in the inner and outer segments on the falling tide. The middle segment was not sampled.

Spring Tides - August 28, 1980

Figure 7 presents current profiles and average longitudinal speeds obtained for the inner, middle, and outer segments of Blair Waterway for August 28, 1980. Currents were stronger on the neap tides and were generally stronger in the outer segment than in the inner segment.

The pattern that developed on the rising tide was very similar to the Hylebos pattern for the small rising tide on August 19, 1980. Flood current was strongest at the surface decreasing to essentially no flow at 3 m, then increasing again at 9 m. In the inner segment, weak flow reversal occurred with the current ebbing on the first half of the rising tide at 3 m.

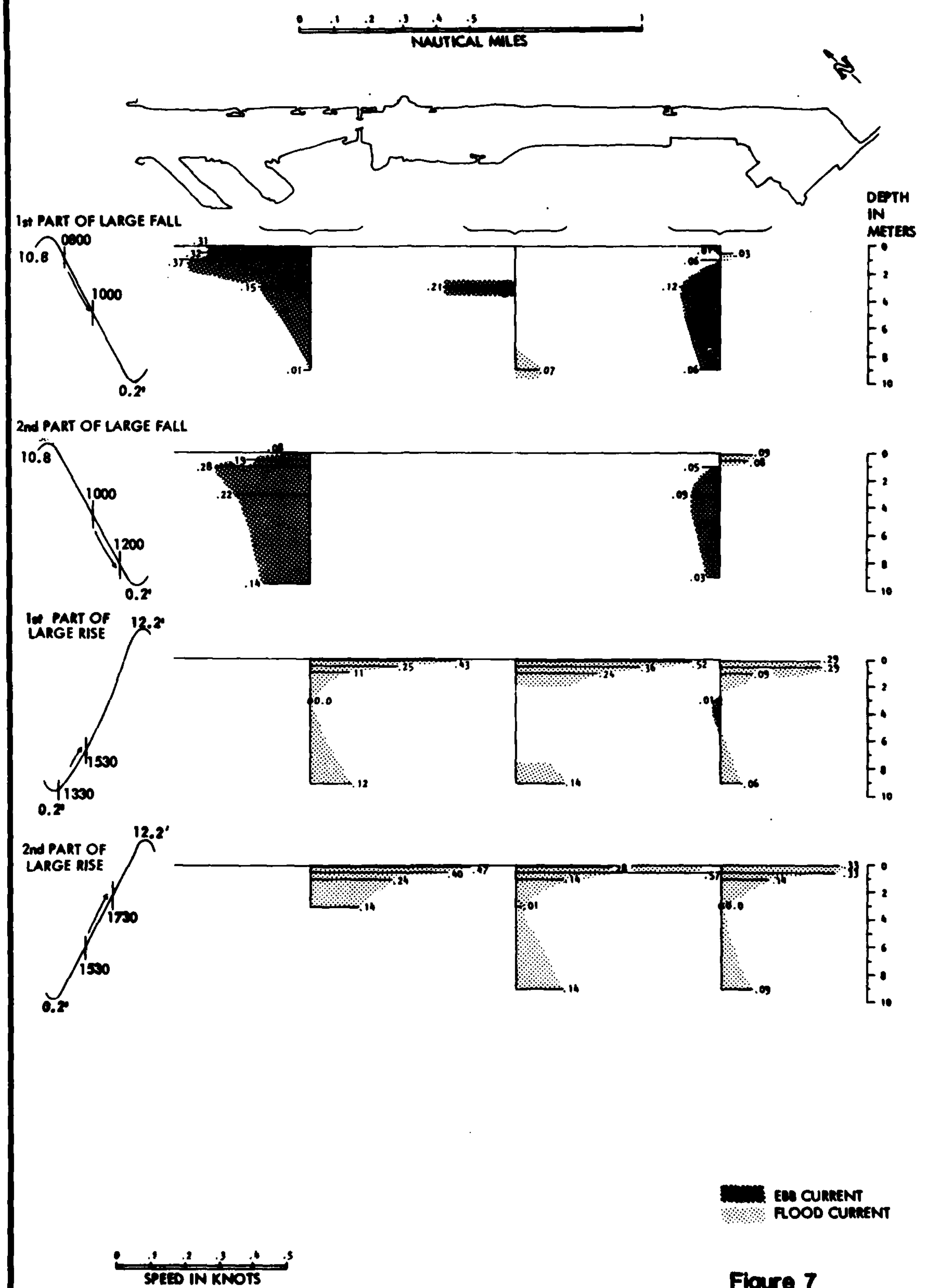

Figure 7
BLAIR WATERWAY
CURRENT PROFILES
28 AUGUST 1980

On the falling tide, strong ebb flow occurred betwen 1 m and 3 m. The surface currents showed resistance to the ebb flow and in the inner segment actually moved in the flood direction, contrary to the tide. The water at 9 m also indicated resistance to ebb flow with flood flow detected in the middle segment on the first half of the falling tide.

The 3-m depth for the large rising tide was remarkably static. For the first 2 hours of the rising tide, the water did not flood in the outer segment but for the next 2 hours it did. The 3-m flow in the middle segment was mainly cross channel. In the inner segment, while the tide was rising 12.5 feet, the flow at 3 m was so slow that 7 observations made on one drogue in 4 hours were within a 200-foot diameter circle.

The similarity between neap rising tides in Hylebos and spring rising tides in Blair suggests a relationship based on the intertidal volume to total volume ratio. Hylebos Waterway is shallower than Blair and the neap tide condition for Hylebos may be hydrodynamically comparable to Blair on the spring tide (see Figures 3 and 7).

2.3.3 Sitcum Waterway

Neap Tides - August 18, 1980

Figure 8 presents current profiles and average longitudinal speeds obtained for the inner and outer segments of Sitcum Waterway on August 18, 1980.

On the rising tide, the water at 0.1 m and 0.5 m behaved identically, flooding at about 0.05 kt in the inner segment for both halves of the tide, while in the outer segment the flood speeds increased from 0.06 kt to 0.26 kt. The water at 1 m flooded very weakly in the inner segment (0.02 to 0.01 kt) while in the outer segment it ebbed at 0.07 kt for the first half of the rising tide, and flooded at 0.13 kt for the last half. At 3 m, the water resisted flood flow but meandered back and forth across the channel. Longitudinal speeds at 3 m for the two segments and the two halves of the rising tide ranged from 0.02 kt ebb to 0.02 kt flood.

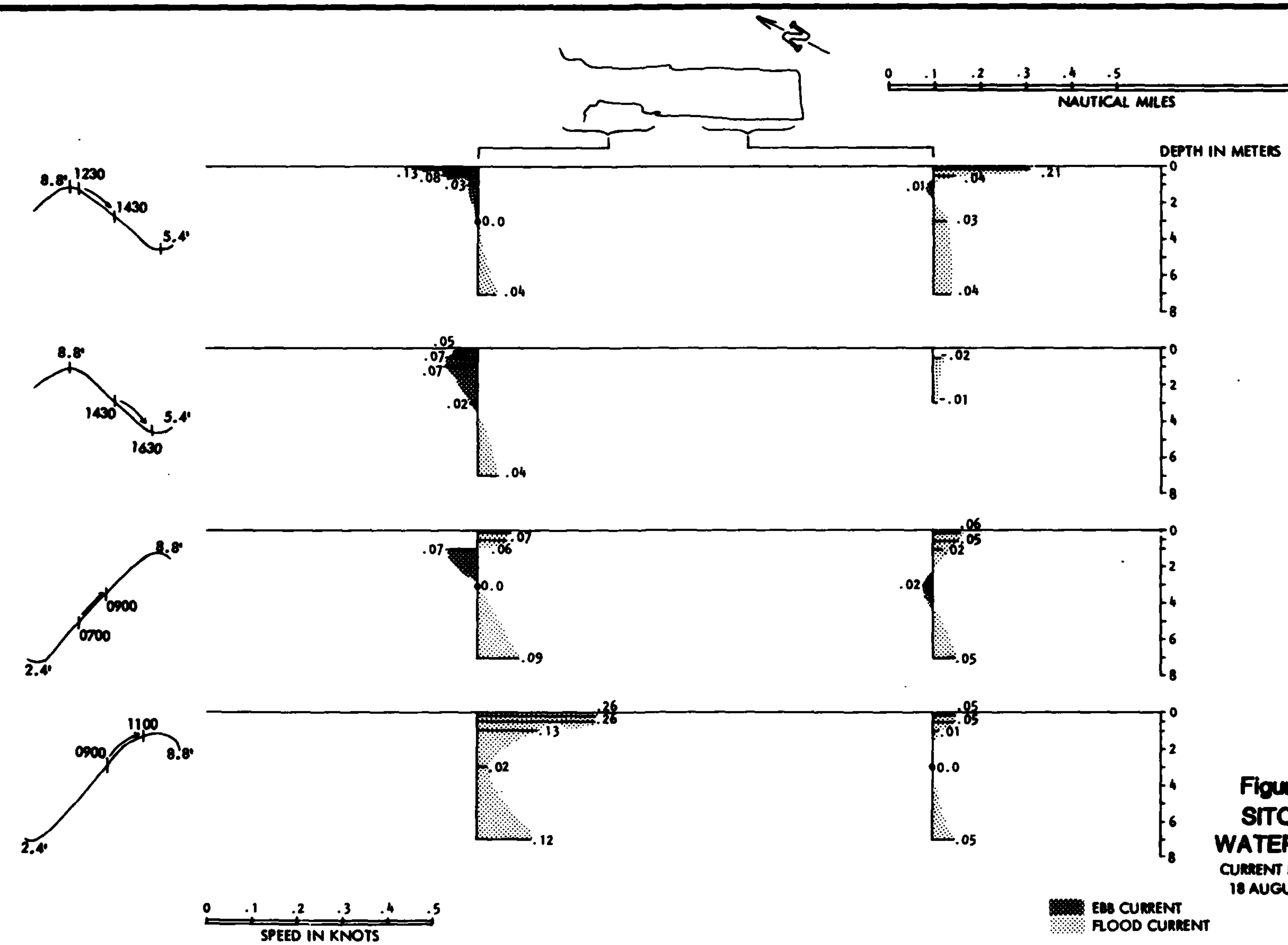

Figure 8
SITCUM
WATERWAY
CURRENT PROFILES
18 AUGUST 1980

At 7 m, the water consistently flooded on the rising tide, being stronger in the outer segment (0.09 to 0.12 kt) and weaker in the inner segment (0.05 kt) during the rising tide. The bottom water continued to flood at about 0.04 kt on the falling tide for both the inner and outer segments. The 3-m water continued to act sluggishly with longitudinal speeds between 0.02 kt ebb to 0.03 kt flood.

Considerable variation was evident in the surface waters with the inner segment flooding and the outer segment ebbing (see Figure 9). The water at 1 m ebbed sluggishly in both the inner and outer segments. One set of drogues launched in the outer segment displayed significant surface shear on the flood tide. The trajectories depicted in Figure 9 show that the surface 0.1 m ebbed steadily while the water at 0.5 m flooded steadily, each drogue essentially reaching the boundary of the waterway within about 3 hours. Meandering flow at 3 m is also evident in Figure 9.

The inner segment of Sitcum Waterway for the rising neap tide exhibited a current profile similar to Hylebos for the rising neap tide and to Blair for the rising spring tide (see Sections 2.3.1, 2.3.2 above). However, the flow for the falling tide did not appear similar to Blair or Hylebos.

Spring Tides - August 27, 1980

Figure 10 presents the current profile and average longitudinal speeds obtained for Sitcum Waterway during the spring tides on August 27, 1980. Strong winds from the southwest created a cross-channel flow driving surface drogues (and surface water) under the piers on the northeast side of Sitcum Waterway. Existing charts and aerial photographs of Sitcum Waterway are misleading with respect to reflecting the actual width of Sitcum Waterway. In actuality, the water extends 30 to 60 feet underneath the pier. Hence, drogue movement continued even after encountering the charted "shoreline" created by the pier.

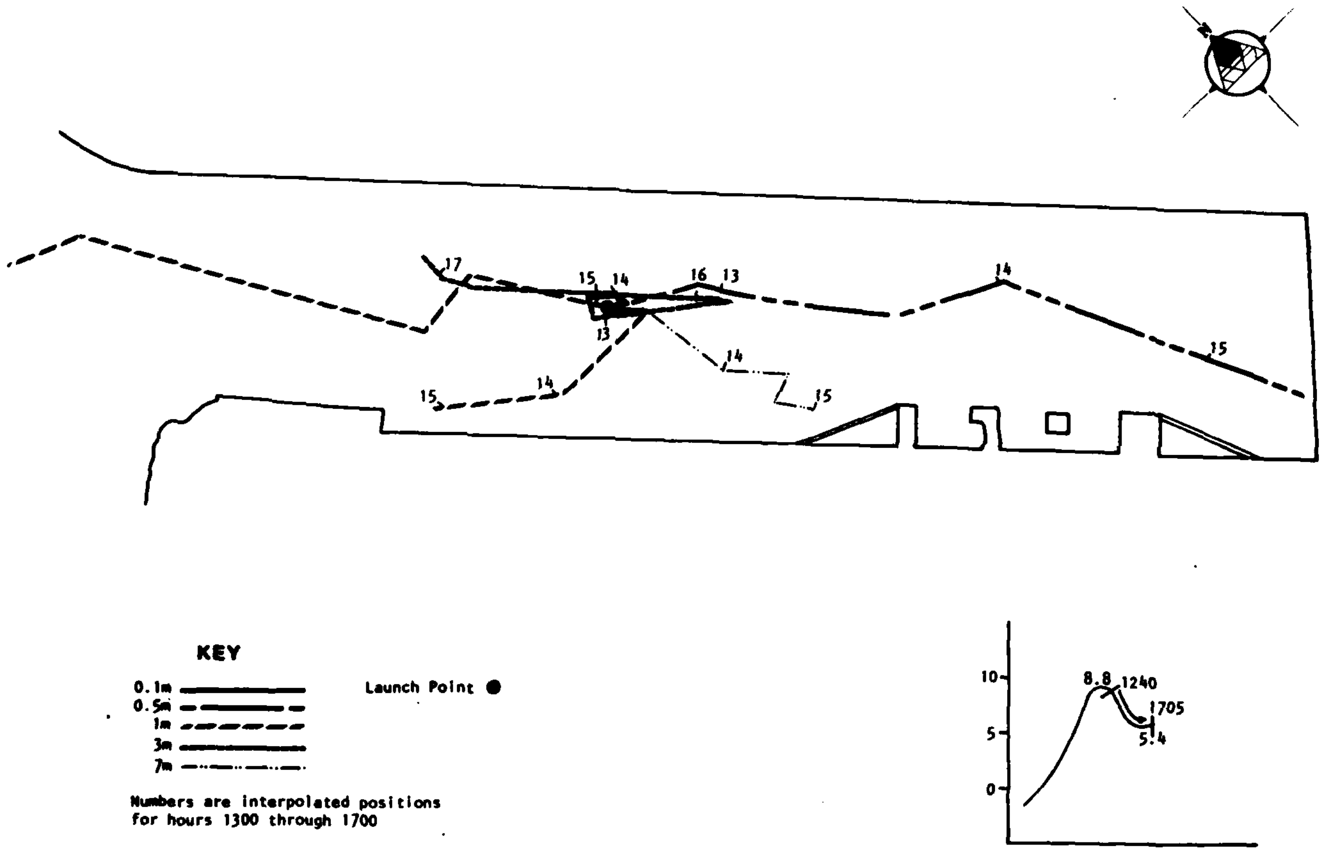

Figure 9
SITCUM WATERWAY FALLING TIDE
DROGUE TRAJECTORIES
Date 8-18-80
Start Time 1145 Recovery Time 1656

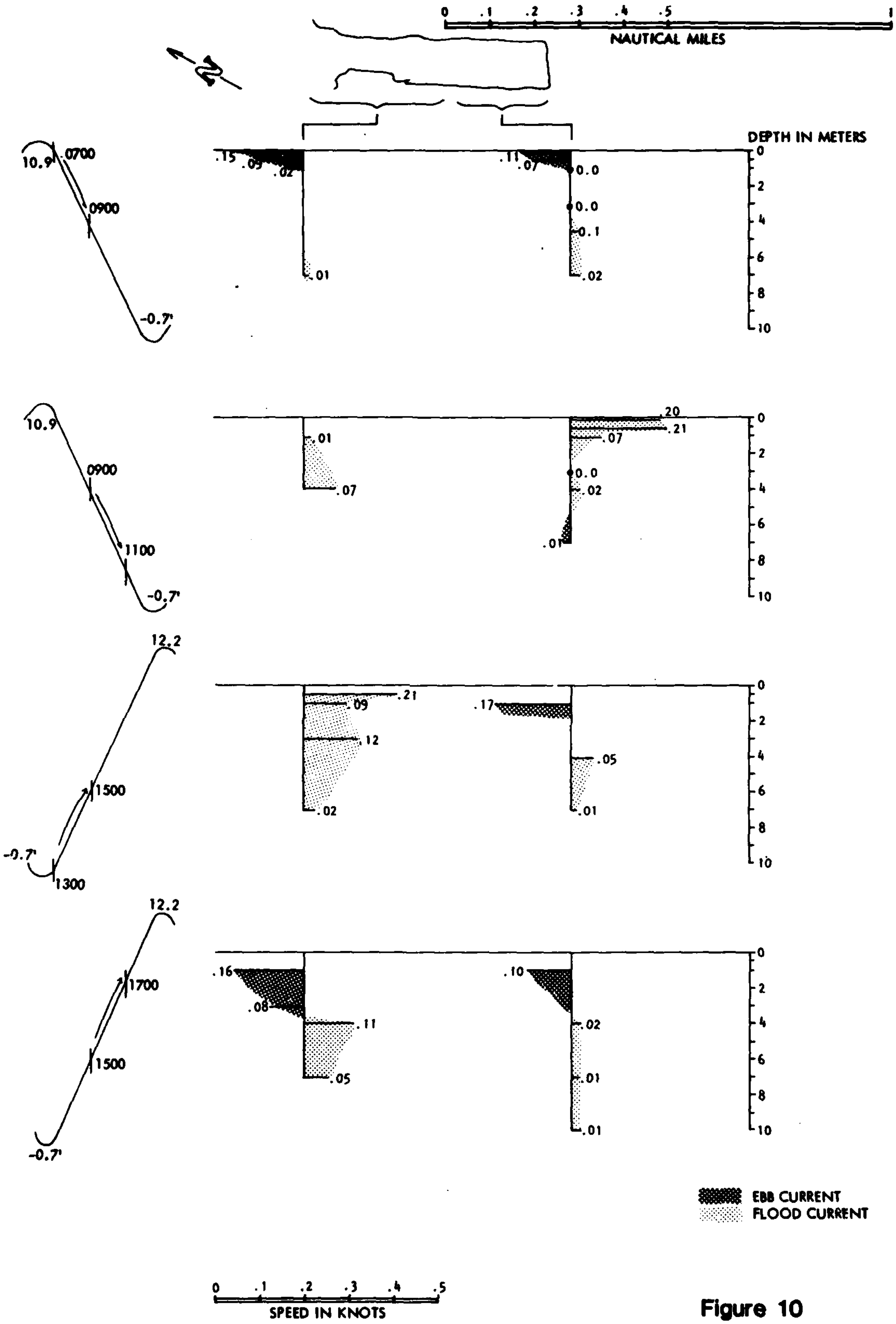

Figure 10
SITCUM WATERWAY
CURRENT PROFILES
27 AUGUST 1980

On the falling tide, the surface flow was ebbing on the first half and flooding on the second half. This is explained by a change in the wind direction resulting in an inward component of motion. The lengths of run for 0.1- and 0.5-m surface drogues were quite short on the falling tide because the wind rapidly drove them cross channel toward the pier. The water at 3 m continued to act sluggish, generally resisting movement in either an ebb or flood direction on the falling tide. On the rising tide, a shear zone at 3 m was observed with ebb flow above and flood flow below.

2.3.4 Milwaukee Waterway

Neap Tides - August 18, 1980 and Spring Tides - August 27, 1980

Figures 11 and 12 present current profiles and average longitudinal speeds obtained for Milwaukee Waterway for neap tides and for spring tides. Because Milwaukee is a short waterway, it was treated as a single unit. Measurements were made concurrently in Sitcum Waterway by the same boat and were given a higher priority in the field program. Consequently, there are fewer observations in Milwaukee Waterway so the current profiles represent the entire rise or fall of tide.

On August 18, 1980 (Figure 11) on the rising tide, the surface waters flooded at about 0.2 to 0.3 kt while the bottom water (7 m) flooded at about 0.2 kt. The water at 3 m essentially remained in place, with minor meandering. On the falling tide the bottom water continued to flood, although at a reduced rate (0.02 kt). The surface water ebbed at about 0.1 kt, and the water at 3 m was motionless. The current profile on the rising tide was similar to the neap tide in Hylebos on August 19, 1980, to the spring tide in Blair on August 28, 1980, and to the neap tide in Sitcum on August 18, 1980. The falling tide profile was similar to the neap tide in Sitcum on August 18, 1980.

On August 27, 1980 (Figure 12), the surface water ebbed weakly on the large falling tide, while the water at 3 m continued to behave as on August 18; that is, remaining stationary. The wa r at 3 m actually had

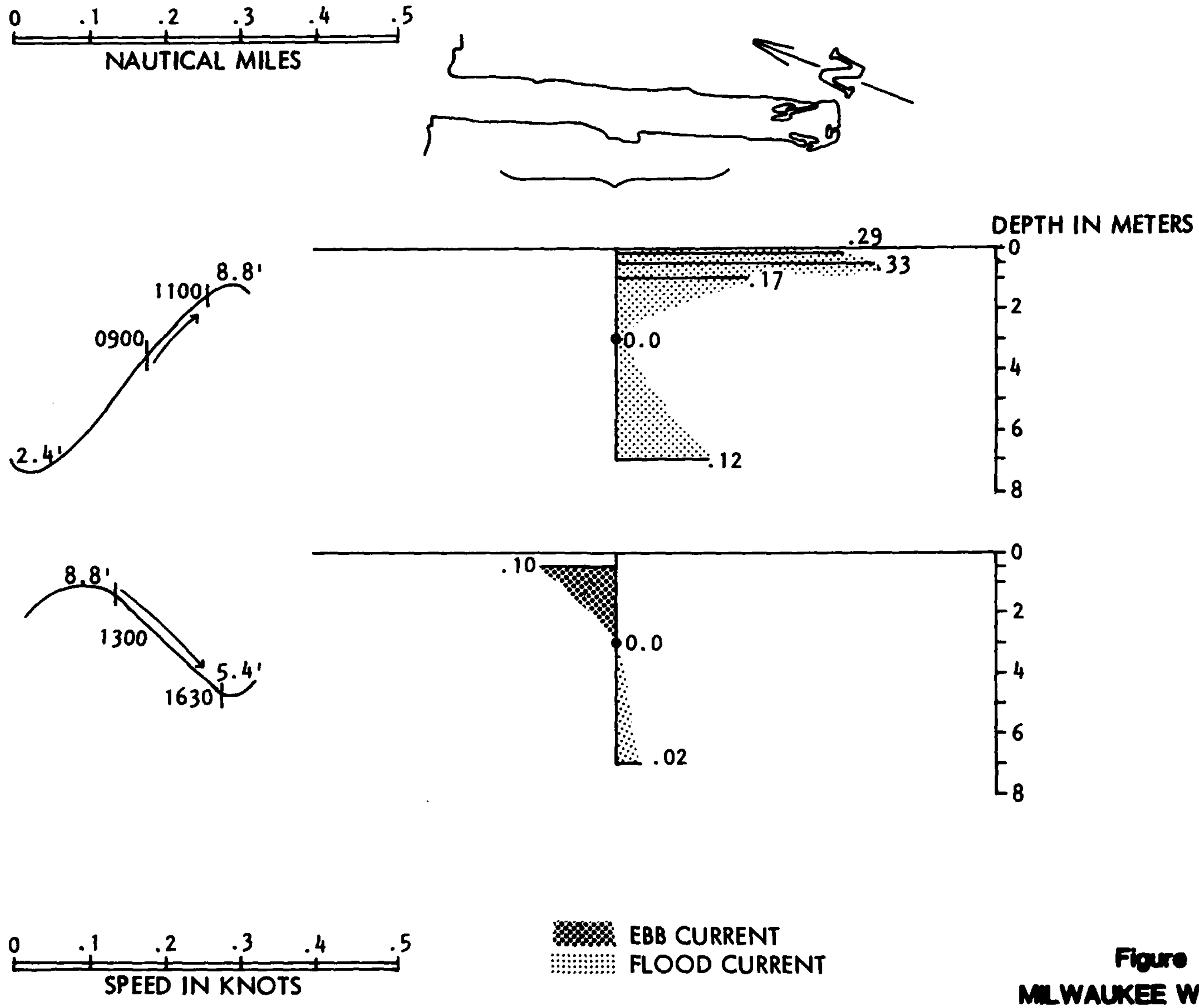

Figure 11
MILWAUKEE WATERWAY
CURRENT PROFILES
18 AUGUST 1980

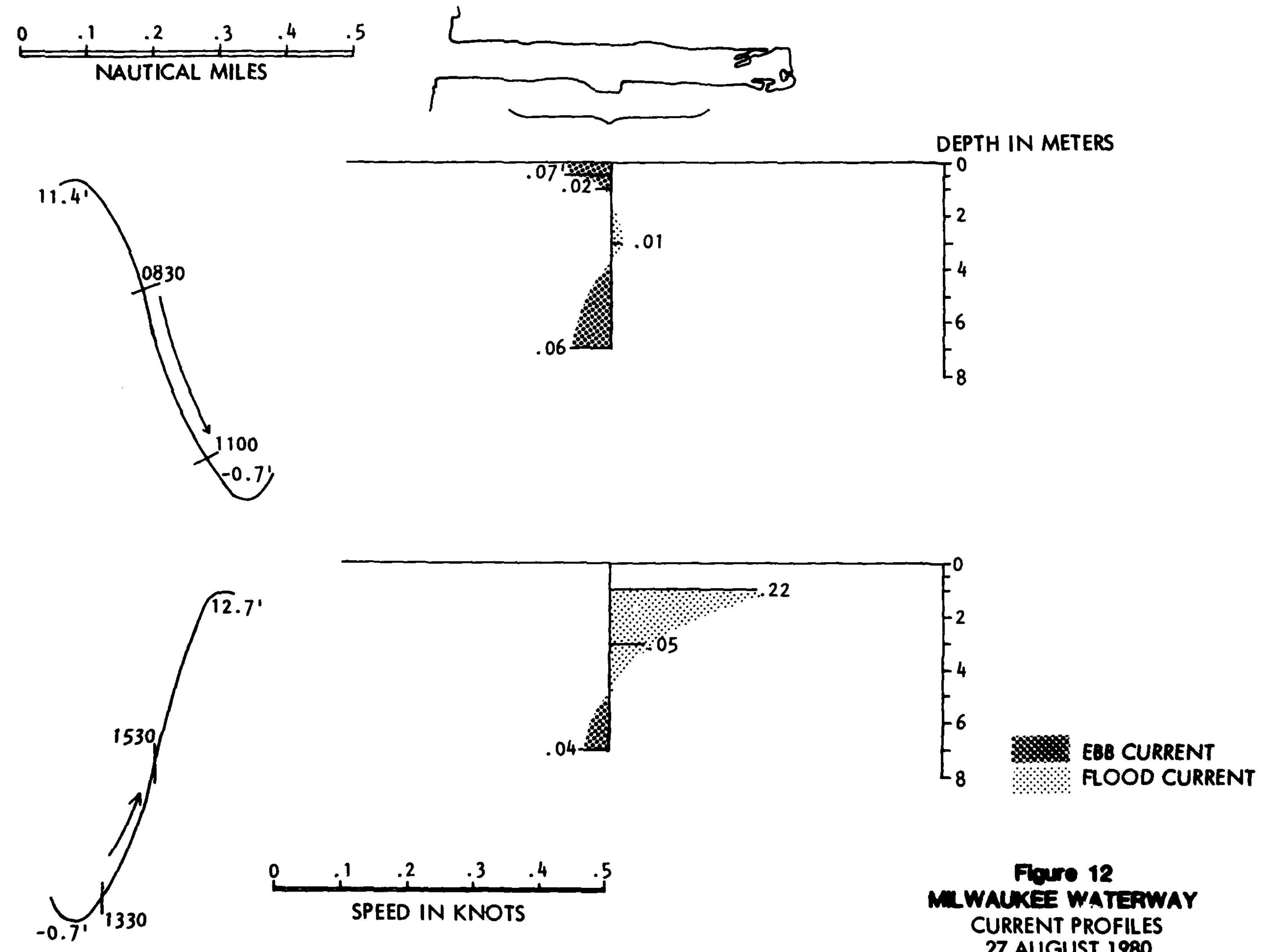

Figure 12
MILWAUKEE WATERWAY
CURRENT PROFILES
27 AUGUST 1980

a very slight flood motion during this falling tide. At 7 m, the water ebbed at 0.06 kt. On the first half of the rising tide, the water at 7 m continued to ebb weakly, while the surface water flooded at greater than 0.2 kt. The water at 3 m on the rising tide was also flooding, but at about one-fourth the speed of the water at 1 m.

2.3.5 Middle Waterway

Neap Tide - August 18, 1980

Figure 13 presents current profiles and average longitudinal speeds obtained for Middle Waterway on August 18, 1980. Because Middle Waterway is a short waterway, it was treated as a single unit. Measurements were made concurrently in City Waterway by the same boat and were given a higher priority in the field program. Consequently, there were fewer observations in Middle Waterway and the current profiles are for only 1 hour of the rising tide and for 3 hours of the falling tide.

Near the end of the rising tide, the water at all depths was flooding, with the greatest speeds at the surface (0.14 kt) and the lowest at the bottom (0.06 kt at 4 m). On the falling tide, the surface continued to flood under the influence of the wind while at 3 m the water ebbed weakly and the bottom water continued to flood.

2.3.6 City Waterway

Neap Tide - August 18, 1980

Figure 14 presents current profiles and average longitudinal speeds obtained for the inner and outer segments of City Waterway for August 18, 1980. Considerable shear was always evident between the surface and 1 m on this date.

On the rising tide, water at 0.1 m was ebbing at about 0.10 to 0.15 kt, 0.5 m was also ebbing weakly (0.01 to 0.05 kt) and 1 m was flooding at 0.03 kt. At the 2-m depth of the inner segment, there was

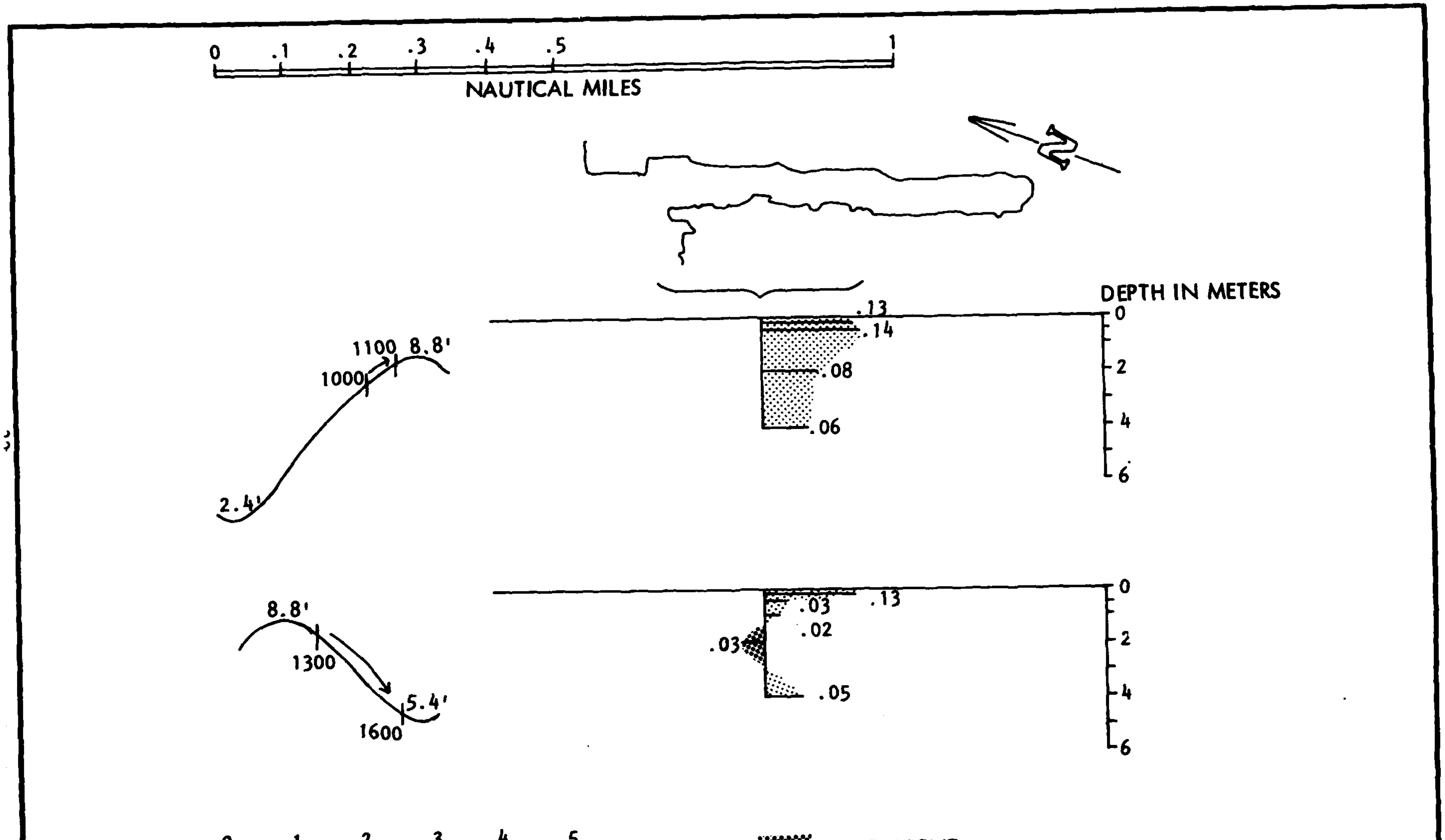

Figure 13
MIDDLE WATERWAY
CURRENT PROFILES
18 AUGUST 1980

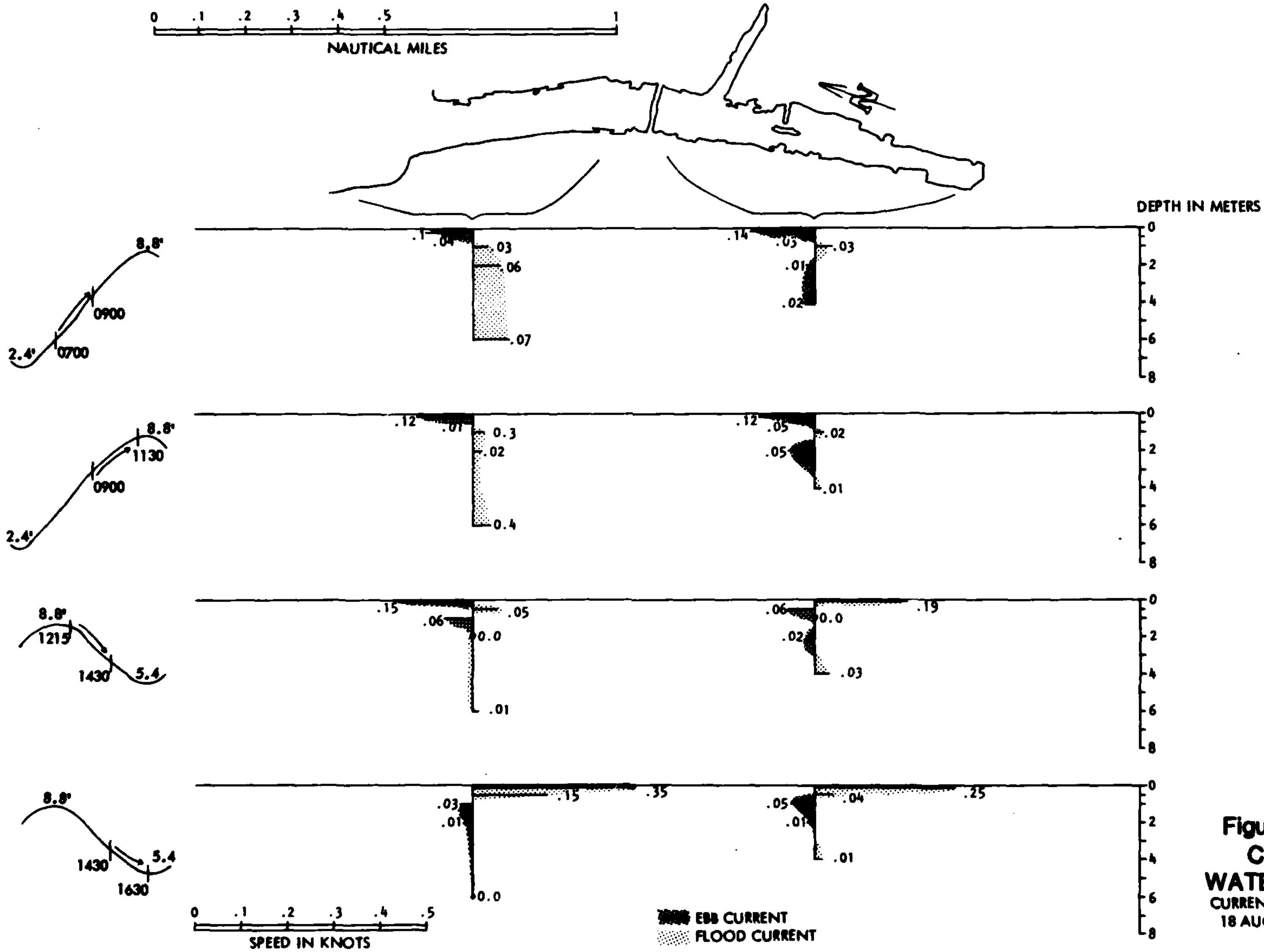

Figure 14
CITY
WATERWAY
CURRENT PROFILES
18 AUGUST 1980

slow cross-channel flow (toward Wheeler Osgood Channel). At 6 m in the outer segment, the current was flooding at about 0.07 kt on the first half of the rising tide and slowed to about 0.04 kt on the last half.

The small afternoon falling tide also exhibited considerable surface shear. At 0.1 m, flood currents of 0.25 to 0.35 kt were attained (in response to the wind) while at 0.5 m, the flow was much weaker. At 1 m and 2 m, the water was ebbing weakly or moving cross-channel. At 4 m and 6 m, the water was essentially stationary.

The profiles in Figure 14 clearly indicate the current shear. Wind effects accounted for the relatively high surface speeds and significant shear in the upper meter. The currents often displayed three or four layers and did not show much similarity to the other waterways. The water was also less turbid, indicating less influence of the Puyallup River.

Spring Tides - August 27 and 29, 1980

Figure 15 presents current profiles and average longitudinal speeds obtained for the inner and outer segments of City Waterway on August 27 and 29, 1980. A boat malfunction on the morning of August 27 necessitated sampling the falling tide on August 29. The large rising and falling tides produced current patterns very similar to those observed on August 18, 1980. However, the speeds obtained in the upper 2 m were considerably greater than those measured during neap tide conditions.

Winds on the last half of the falling tide on August 29, 1980 reversed the surface flow, creating a shear zone in the upper 1 meter. Throughout the falling tide, water at 6 m continued to move into the waterway and at 4 m the water was motionless. On the first half of the falling tide, the upper 2 m flowed seaward at 0.18 to 0.25 kt in the outer segment and 0.06 to 0.11 kt in the inner segment. Although no drogues were set at 3 m, it is inferred that very little motion occurred at this depth because of opposing flows above and below in the inner segment. In the outer segment, strong ebb flow occurred at 1 and 2 m.

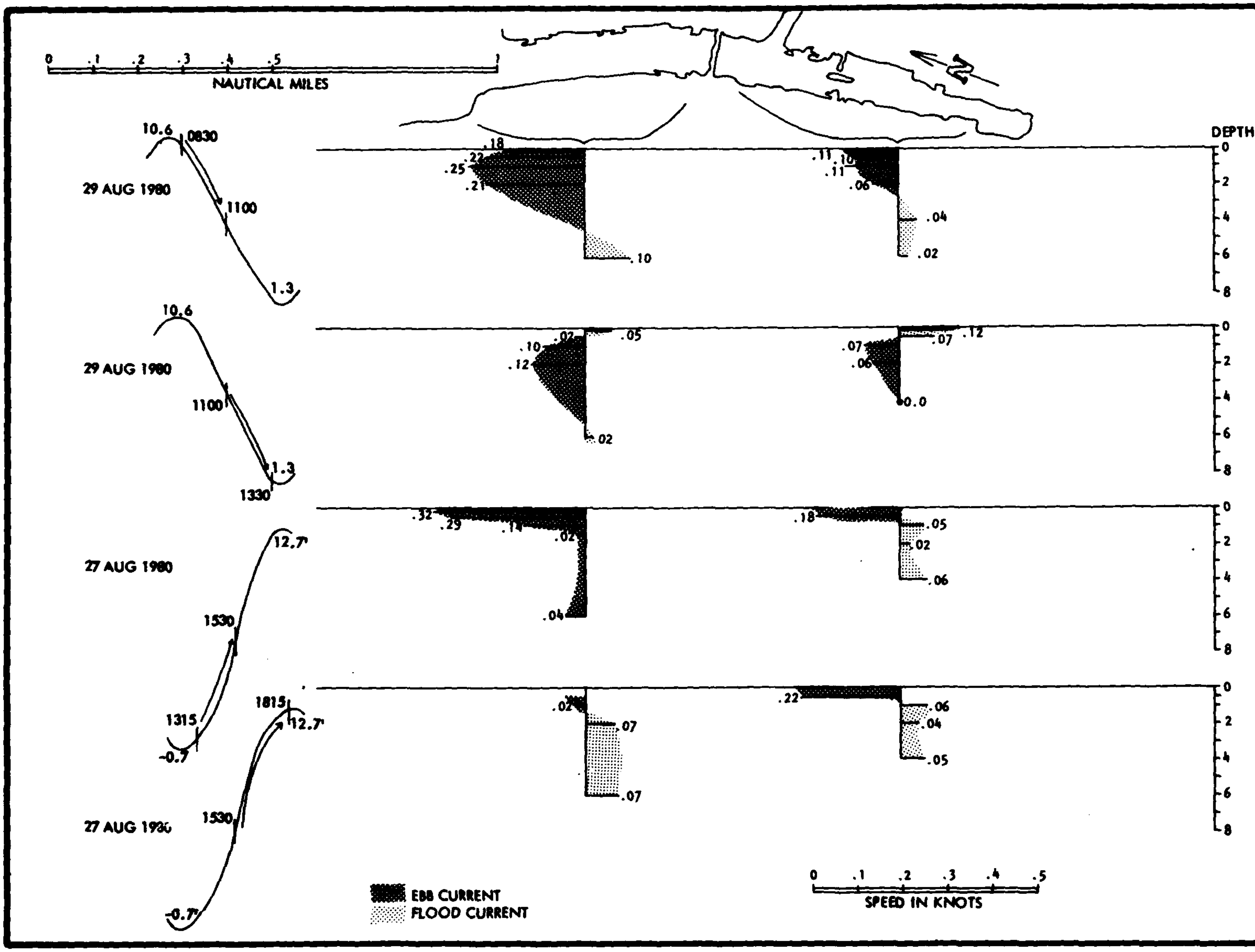

Figure 15
CITY WATERWAY
CURRENT PROFILES
27-29 AUGUST 1980

The large rising tide was sampled on August 27. Winds from the south (10 to 20 kt) were present in the area that day. These wind conditions created a well-pronounced surface flow out of the waterway (opposing the rise of the tide) with longitudinal speeds in the outer segment ranging from 0.14 to 0.32 kt from the surface to a depth of 0.5 m. In the inner segment, this flow was evident in the upper half meter, but was not as strong. At 0.1 m in the inner segment, the water was flooding at 0.05 kt on the first half of the rising tide. Two drogues at 0.5 m in the inner segment did ebb at 0.22 kt in opposition to the tide. The water from 1 m to 4 m flooded steadily in the inner segment for both halves of the rising tide, with speeds ranging from 0.02 to 0.06 kt. During the last half of the rising tide, the water from 2 to 6 m was flooding at 0.07 kt in the outer segment; however, water was ebbing slowly at those depths for the first half of the rising tide. Thus, measurements at all the depths sampled (0.1 m, 0.5 m, 1 m, 2 m, and 6 m) indicated that water was ebbing on the rising tide for the outer segment of City Waterway. It is possible that all the water on the east side of this segment would flow seaward due to the wind and the bend in the waterway. The drogues were concentrated more on the east side of the waterway because marine piers on the west side limited the use of drogues. Hence, drogues were launched with a bias to the east side of the waterway in this segment. Because the tide was rising, water had to be entering City Waterway at a faster rate than it was leaving. The incoming water could also have been between the 2-m and 6-m depths or below the 6-m depth of our drogues. On the other hand, the water could have had a net southerly flow (flood) on the western side of City Waterway (near and under the marina piers). We feel that this second alternative is more plausible.

The current profiles for August 27 - 29, 1980 showed considerable similarilty to the neap tides of August 18 (see Figure 14). Although speeds and transport observed were greater, many of the same layers and shear zones are still defined.

2.4 WINTER STUDY RESULTS - BLAIR WATERWAY

2.4.1 General

Drogue trajectories obtained from the concentrated winter study in Blair Waterway are presented in the appendix and are numbered as follows:

Figure 16-0 = outer segment, first half small rising tide
Figure 16-M = middle segment, first half small rising tide
Figure 16-I = inner segment, first half small rising tide

Figure 17-0 = outer segment, last half small rising tide
Figure 17-M = middle segment, last half small rising tide
Figure 17-I = inner segment, last half small rising tide

Figure 18-0 = outer segment, first half large falling tide
Figure 18-M = middle segment, first half large falling tide
Figure 18-I = inner segment, first half large falling tide

Figure 19-0 = outer segment, last half large falling tide
Figure 19-M = middle segment, last half large falling tide
Figure 19-I = inner segment, last half large falling tide

Figure 20-0 = outer segment, first half large rising tide
Figure 20-M = middle segment, first half large rising tide
Figure 20-I = inner segment, first half large rising tide

Figure 21-0 = outer segment, last half large rising tide
Figure 21-M = middle segment, last half large rising tide

Figure 22-0 = outer segment, first half small falling tide
Figure 22-M = middle segment, first half small falling tide
Figure 22-I = inner segment, first half small falling tide

Figure 23-0 = outer segment, last half small falling tide
Figure 23-M = middle segment, last half small falling tide
Figure 23-I = inner segment, last half small falling tide

Figure 24-0 = outer segment, first half small rising tide
Figure 24-M = middle segment, first half small rising tide

The coding of the figure numbers is such that any given number represents a particular half of a tide, and the letter O, M, or I represents the outer, middle, or inner segment of the waterway.

Tables 2.16 through 2.24 (in the appendix) present observed speeds and directions for drogues within Blair Waterway with the numbers after the decimals keyed to the number of the corresponding figure. These tables are broken down to outer, middle, and inner segments.

Current profiles and average longitudinal speeds obtained on consecutive small and large falling and rising tides on February 17 - 18, 1981 for the inner, middle, and outer segments of Blair Waterway are presented in Figures 25.16 through 25.24 (in the appendix). The numbers after the decimal are keyed to the trajectory figure numbers of 16 through 24.

Current meter data obtained from a moored vessel in the middle segment of Blair Waterway are presented in Table 3.

Profiles of salinity distribution within Blair Waterway, as constructed from CSTD data, are presented in Figures 26, 27, and 28 for successive high, low, and falling tides during the winter study period.

2.4.2 Small Rising Tide - February 17, 1981

Figures 16 (O, M, and I) and 17 (O, M, and I) in the appendix present trajectories for drogues at 0.1 m, 0.5 m, 1 m, 2 m, 3 m, 4 m, 6 m, and 10 m for the first half and second half of a rising tide of 4.7 feet. Tables 2.16 and 2.17 in the appendix present depth, time, location, speed, and direction information on these drogues. Figures 25.16 and 25.17 in the appendix present the longitudinal current profiles for the first and last half of this small rising tide. The observations for the last half actually extended 40 minutes past the high tide at 1521.

Winds during this period were from the south to southwest at 5 to 10 kt as measured from the moored vessel in the middle segment. Ebb flow at the surface persisted in all segments throughout the rising tide as surface water was driven by the wind. Speeds in the upper half-meter varied from 0.04 to 0.31 kt. Flood flow was well pronounced (0.10 to 0.13 kt) at 10 m in the outer segment, but was negligible at 10 m in the middle and inner segment. The water from 3 to 6 m was

TABLE 3

CURRENT METER OBSERVATIONS FROM MOORED BOAT [(a)]

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1129	0.6	0.16	335
	1.5	0.10	295
	3.1	0.10	260
1132	4.6	0.04	-
	6.1	0.24	080
1134	7.6	0.24	240
	9.1	0.04	290
1137	10.7	0.09	290
	12.2	0.15	110
1139	13.7	0.12	260

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1217	0.6	0.11	310
1218	1.5	0.19	260
1219	3.1	0.19	080
1221	4.6	0.11	285
1222	6.1	0.15	120
1224	7.6	0.11	110
1225	9.1	0.06	220
1226	10.7	0.11	-
1226	12.2	0.10	260
1227	13.7	0.11	260

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1245	0.6	0.19	020
1248	1.5	0.08	230
1251	3.1	0.14	270
1253	4.6	0.09	245
1254	6.1	0.16	110
1257	7.6	0.11	250
1257	9.1	0.13	230
1259	10.7	0.17	270
1300	12.2	0.23	260
1301	13.7	0.15	085

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1339	0.6	0.13	355
1340	1.5	0.13	270
1341	3.1	0.13	290
1342	4.6	0.07	
1344	6.1	0.05	240
1346	7.6	0.06	
1347	9.1	0.09	100
1350	10.7	0.18	230
1351	12.2	0.16	090
1354	13.7	0.13	270

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1416	0.1	0.10	290
1417	1.5	0.25	270
1417	3.1	0.07	275
1417	4.6	0.14	245
1419	6.1	0.15	290
1420	7.6	0.22	290
1420	9.1	0.15	295
1422	10.7	0.20	290
1422	12.2	0.19	300
1423	13.7	0.15	130

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1444	0.1	0.10	290
1445	1.5	0.11	130
1447	3.1	0.22	300
1447	4.6	0.25	280
1448	6.1	0.20	300
1448	7.6	0.20	275
1449	9.1	0.21	280
1451	10.7	0.25	270
1451	12.2	0.22	265
1452	13.7	0.11	110

(a) Time in Pacific Standard time, depth in meters, speed in knots, direction in degrees true.

TABLE 3

Sheet 2 of 8

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1515	0.1	0.22	090
1516	1.5	0.16	280
1520	3.1	0.20	280
1520	4.6	0.27	285
1520	6.1	0.11	295
1521	7.6	0.10	325
1522	9.1	0.08	050
1523	10.7	0.12	080
1523	12.2	0.12	245
1524	13.7	0.11	245

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1542	0.1	0.18	120
1542	1.5	0.26	050
1543	3.1	0.25	005
1544	4.6	0.25	255
1546	6.1	0.15	090
1546	7.6	0.15	315
1547	9.1	0.12	295
1547	10.7	0.21	255
1549	12.2	0.12	265
1549	13.7	0.15	250

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1622	0.6	0.04	075
1624	1.5	0.08	000
1625	3.1	0.10	320
1626	4.6	0.07	290
1628	6.1	0.07	340
1629	7.6	0.10	290
1629	9.1	0.09	290
	10.7	0.23	270
1634	12.2	0.11	290
1636	13.7	0.06	130

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1642	0.6	0.06	050
1643	1.5	0.04	225
1645	3.1	0.02	264
1648	4.6	0.05	095
1649	6.1	0.03	260
1649	7.6	0.05	280
1650	9.1	0.13	160
1653	10.7	0.05	310
1653	12.2	0.06	250
1654	13.7	0.05	145

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1726	0.6	0.25	320
1727	1.5	0.65	250
1727	3.1	0.11	290
1727	4.6	0.17	285
1728	6.1	0.05	290
1729	7.6	0.06	315
1729	9.1	0.09	300
1730	10.7	0.12	285
1730	12.2	0.07	285
1731	13.7	0.02	320

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1746	0.6	0.06	
1747	1.5	0.11	
1748	3.1	0.13	
1749	4.6	0.05	
1750	6.1	0.06	
1751	7.6	0.05	345
1752	9.1	0.07	055
1752	10.7	0.11	055
1754	12.2	0.10	260
1755	13.7	0.10	170
1756	6.1	0.17	345
1758	3.1	0.04	245
1759	0.6	0.15	275

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1814	0.6	0.06	145
1815	1.5	0.10	150
1815	3.1	0.11	165
1816	4.6	0.04	260
1818	6.1	0.11	270
1819	7.6	0.09	330
1819	9.1	0.07	320
1821	10.7	0.06	105
1822	12.2	0.04	035
1823	13.7	0.0	-

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1846	0.6	0.08	345
1847	1.5	-	-
1848	3.1	0.06	270
1851	4.6	0.17	000
1853	6.1	0.16	340
1855	7.6	0.30	350
1859	9.1	0.18	220
1901	10.7	0.09	010
1902	12.2	0.12	260
1903	13.7	-	-

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1924	0.6	0.13	180
1926	1.5	0.17	175
1927	3.1	0.14	340
1928	4.6	0.04	055
1930	6.1	0.12	265
1932	7.6	0.11	320
1933	9.1	0.08	005
1935	10.7	0.12	005
1936	12.2	0.10	050

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
1945	0.6	0.05	
1946	1.5	0.13	250
1948	3.1	0.06	340
1948	4.6	0.09	345
1949	6.1	0.12	305
1950	7.6	0.09	300
1952	9.1	0.12	040
1953	10.7	0.03	260
1954	12.2	0.05	330

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
2024	0.6	0.07	260
2025	1.5	0.22	000
2027	3.1	0.07	320
2028	4.6	0.22	230
2029	6.1	0.09	333
2030	7.6	0.13	005
2033	9.1	0.05	100
2037	10.7	0.23	195
2042	12.2	0.20	000
2055	0.6	0.15	330
	0.6	0.17	290
	1.5	0.08	260

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
2110	0.6	0.5	170
2111	1.5	0.08	260
2112	3.1	0.03	020
2113	4.6	0.08	050
2114	7.6	0.08	080
2114	9.1	0.07	000
2116	10.7	0.10	005
2117	12.2	0.03	075

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
2133	0.6	0.11	255
2134	1.5	0.09	195
2136	3.1	0.09	230
2138	4.6	0.10	315
2139	6.1	0.11	340
2140	7.6	0.09	320
2140	9.1	0.05	260
2141	10.7	0.04	-

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
2216	0.6	0.16	260
2216	1.5	0.10	000
2217	3.1	0.10	345
2217	4.6	0.16	310
2217	6.1	0.21	310
2217	7.6	0.10	320
2218	9.1	0.13	320
2220	10.7	0.05	060

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
2316	0.6	0.04	265
2317	1.5	0.02	230
2318	3.1	0.01	230
2319	4.6	0.0	-
2320	6.1	0.0	-
2321	7.6	0.03	220
2322	9.1	0.02	210
2322	10.7	0.02	210
2324	12.2	0.02	060

DATE: 17 Feb 81

Time	Depth	Spd.	Dir.
2355	0.6	0.06	110
2356	1.5	0.0	-
2357	3.1	0.0	-
2357	4.6	0.0	-
2358	6.1	0.0	-
2359	7.6	0.04	200
2400	9.1	0.06	150
2400	10.7	0.05	355
2401	12.2	0.02	180

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0015	0.6	0.05	030
0016	1.5	0.0	-
0017	3.1	0.03	150
0018	4.6	0.04	165
0018	6.1	0.04	170
0019	7.6	0.07	170
0020	9.1	0.08	175
0021	10.7	0.03	160
0022	12.2	0.05	160

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0045	0.6	0.05	175
0046	1.5	0.05	175
0047	3.1	0.04	020
0048	4.6	0.05	005
0049	6.1	0.12	110
0049	7.6	0.15	165
0050	9.1	0.16	210
0051	10.7	0.17	190
0051	12.2	0.13	060

TABLE 3

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0117	0.6	0.15	185
0119	1.5	0.06	170
0123	3.1	0.08	000
0125	4.6	0.07	140
0126	6.1	0.08	150
0127	7.6	0.06	140
0128	9.1	0.15	005
0129	10.7	0.11	090
0130	12.2	0.10	095
0131	13.7	0.07	180

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0154	0.6	0.15	-
0155	1.5	0.15	-
0156	3.1	0.03	290
0157	4.6	0.05	040
0158	6.1	0.05	170
0200	7.6	0.11	100
0202	9.1	0.04	070
0203	9.1	0.07	350
0205	10.7	0.07	140
0207	12.2	0.16	120
0209	13.7	0.08	355

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0227	0.6	0.26	170
0230	1.5	0.15	170
0231	3.1	0.04	335
0232	4.6	0.03	050
0236	6.1	0.12	150
0237	7.6	0.05	170
0238	9.1	0.06	225
0241	10.7	0.36	215
0243	12.2	0.07	320

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0342	0.6	0.39	145
0344	1.5	0.17	140
0345	3.1	0.32	120
0346	4.6	0.17	320
0346	6.1	0.18	120
0347	7.6	0.19	145
0347	9.1	0.18	170
0350	10.7	0.25	145
0352	12.2	0.32	270

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0422	0.6	0.15	
0423	1.5	0.31	140
0425	3.1	0.16	290
0427	3.1	0.09	170
0427	4.6	0.16	170
0429	6.1	0.07	290
0431	7.6	0.10	180
0432	9.1	0.15	160
0433	10.7	0.17	320

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0500	0.6	0.13	290
0501	1.5	0.10	340
0501	3.1	0.14	170
0502	4.6	0.10	170
0504	6.1	0.04	210
0505	7.6	0.07	205
0506	9.1	0.11	230
0507	10.7	0.05	290
0509	12.2	0.15	140

TABLE 3

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0531	0.6	0.15	110
0532	1.5	0.05	345
0533	3.1	0.13	280
0533	4.6	0.07	270
0534	6.1	0.08	185
0536	7.6	0.04	300
0537	9.1	0.06	230
0538	10.7	0.06	180
0539	12.2	0.02	190

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0600	0.6	0.13	050
0601	1.5	0.04	070
0603	3.1	0.01	250
0604	4.6	0.04	090
0605	6.1	0.03	260
0606	7.6	0.07	215
0608	9.1	0.07	170
0608	10.7	0.07	110
0609	12.2	0.07	240

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0629	0.6	0.15	340
0630	1.5	0.09	350
0631	3.1	0.14	210
0632	4.6	0.07	010
0633	6.1	0.08	025
0634	7.6	0.08	050
0635	9.1	0.07	215
0636	10.7	0.14	215
0636	12.2	0.09	210
0637	13.7	0.02	040

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0728	0.6	0.12	050
0728	1.5	0.11	000
0728	3.1	0.28	350
0728	4.6	0.32	290
0729	6.1	0.10	255
0729	7.6	0.14	230
0730	9.1	0.26	230
0730	10.7	0.23	270
0730	12.2	0.27	280

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0818	0.6	0.26	290
0819	1.5	0.21	295
0819	3.1	0.20	285
0820	4.6	0.23	290
0820	6.1	0.14	280
0821	7.6	0.05	170
0822	9.1	0.22	140
0822	10.7	0.26	080
0823	12.2	0.16	275

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0846	0.6	0.04	310
0848	1.5	0.06	330
0850	3.1	0.10	095
0852	4.6	0.18	285
0854	6.1	0.11	080
0855	7.6	0.04	170
0856	9.1	0.06	110
0857	10.7	0.08	060
0858	12.2	0.15	305

TABLE 3

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0916	0.6	0.11	280
	1.5	0.07	335
	3.1	0.02	295
	4.6	0.05	320
0919	6.1	0.09	295
	7.6	0.10	295
	9.1	0.07	330
	10.7	0.10	310
	12.2	0.03	270

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
0947	0.6	0.11	310
	1.5	0.12	310
	3.1	0.11	330
	4.6	0.11	310
0951	6.1	0.07	140
0952	7.6	0.14	330
0952	9.1	0.09	350
	10.7	0.10	310
0954	12.2	0.06	260

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
1016	0.6	0.28	310
	1.5	0.21	170
	3.1	0.07	200
1020	4.6	0.20	330
	6.1	0.19	320
	9.1	0.15	165
1022	10.7	0.16	165
1024	12.2	0.33	305

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
1044	0.6	0.08	260
	1.5	0.08	210
	3.1	0.08	170
	4.6	0.07	150
	6.1	0.10	160
	7.6	0.04	150
	9.1	0.07	220
	10.7	0.05	190
1050	12.2	0.10	160

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
1113	0.6	0.08	350
	1.5	0.05	170
1116	3.1	0.06	200
	4.6	0.04	230
1118	6.1	0.04	310
	7.6	0.03	160
	9.1	0.04	235
	10.7	0.06	260
	12.2	0.0	-

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
1147	0.6	0.09	225
1148	1.5	0.09	220
1149	3.1	0.11	208
1151	4.6	0.18	130
1152	6.1	0.09	270
1153	7.6	0.09	250
1156	9.1	0.13	180
1155	10.7	0.14	030
1155	12.2	0.12	040

DATE: 18 Feb 81

Time	Depth	Spd.	Dir.
1239	0.6	0.10	330
1240	1.5	0.07	230
1241	3.1	0.19	220
1241	4.6	0.13	230
1242	6.1	0.13	230
1242	7.6	0.12	230
1243	9.1	0.08	220
1243	10.7	0.10	195
1244	12.2	0.15	200

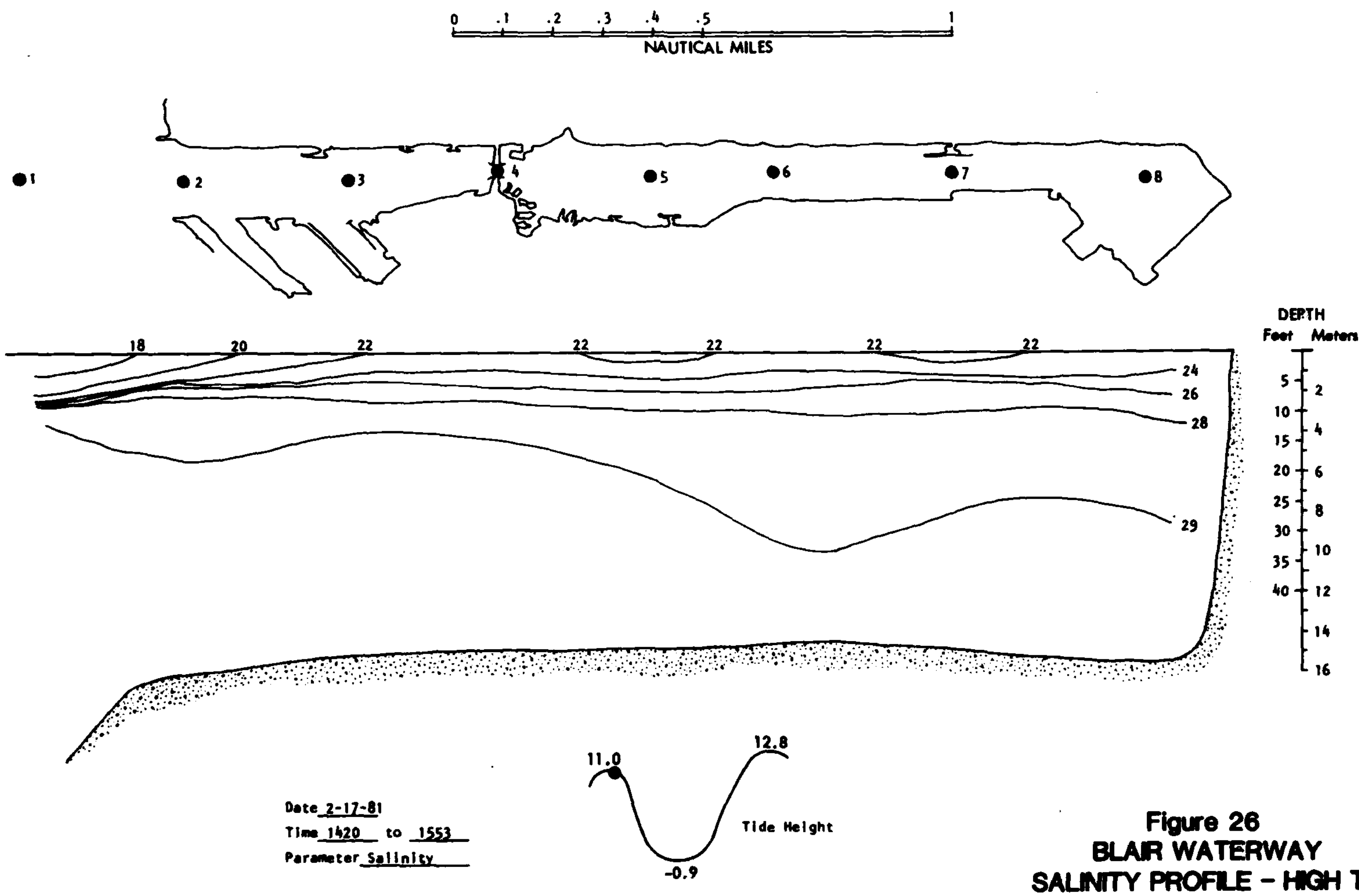

Figure 26
BLAIR WATERWAY
SALINITY PROFILE - HIGH TIDE

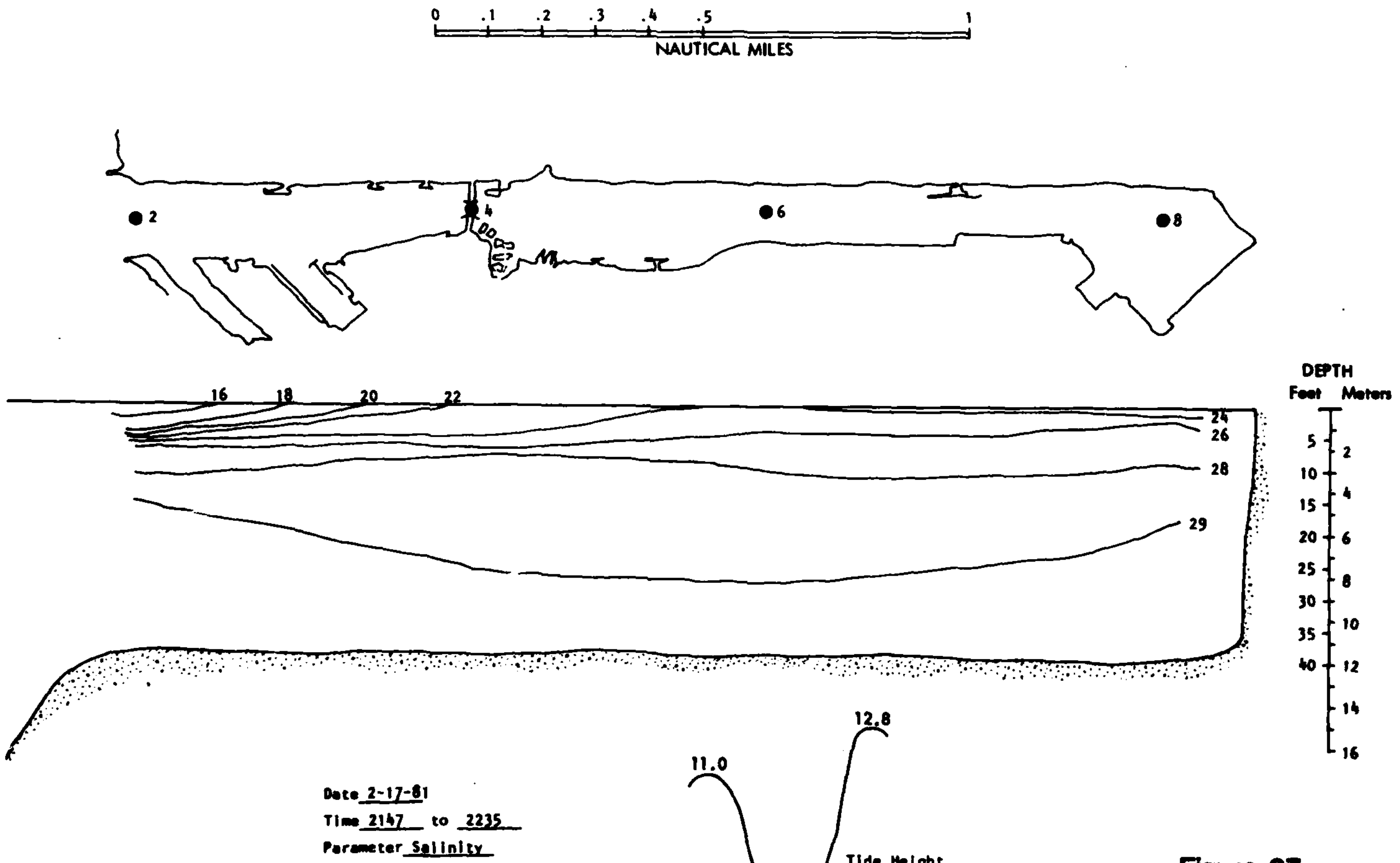

Figure 27
BLAIR WATERWAY
SALINITY PROFILE - LOW TIDE

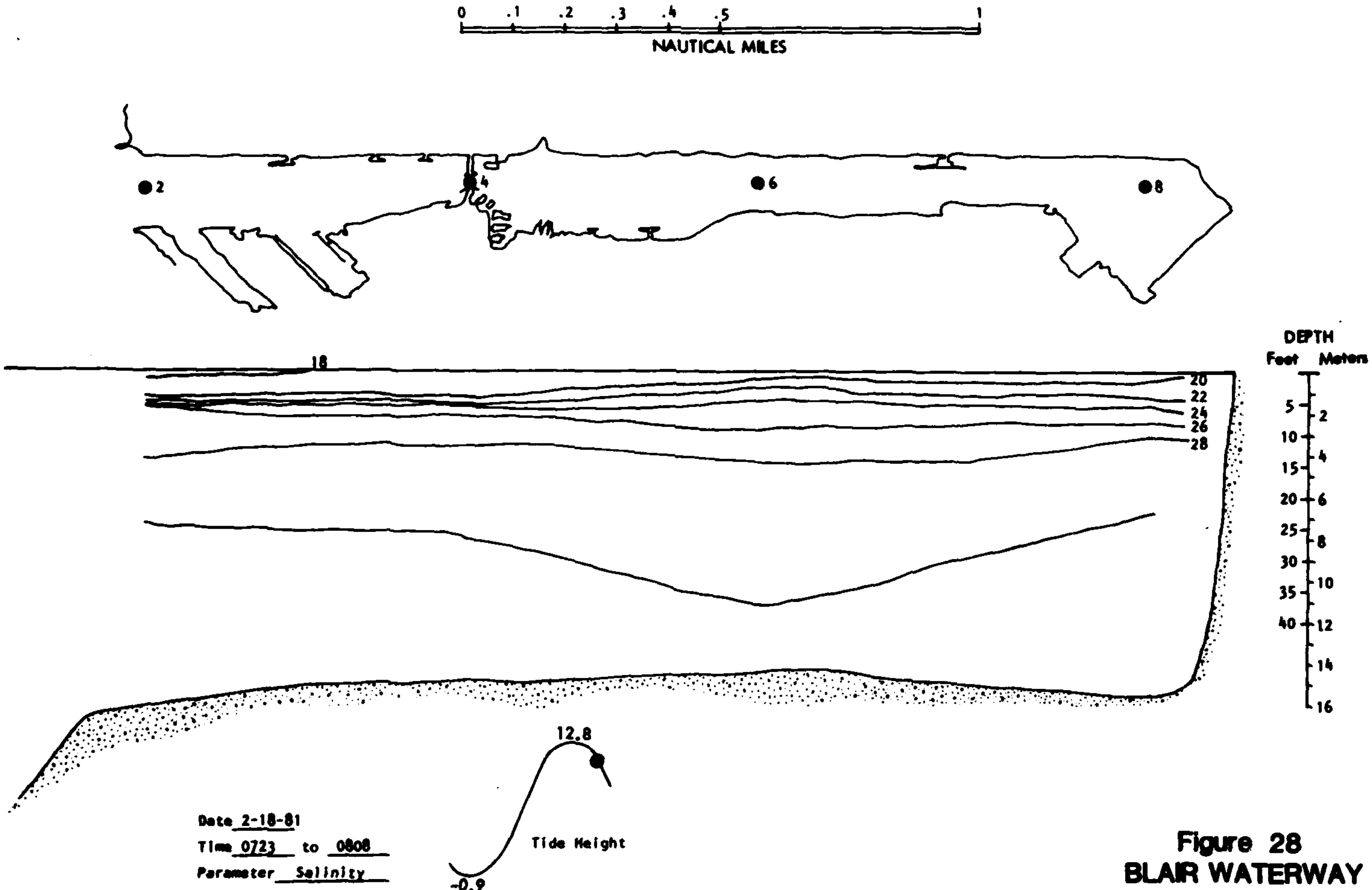

Figure 28
BLAIR WATERWAY
SALINITY PROFILE – FALLING TIDE

flooding at the first half of the rising tide in the middle segment. On the last half of the rising tide, ebb flow occurred at 3 and 4 m while flood flow occurred just above (2 m) and below (6 m). Cross-channel flow in the middle segment on the first half of the rising tide was significant. The surface down to 1 m flowed seaward, water at the 2-m depth flowed toward the northern shore, while water at 3 m flowed toward the southern shore and water at 4 m and 6 m was flowing in (flooding). Water at 10 m flowed toward the northern shore. Figure 16-M in the appendix presents the trajectories illustrating this cross-channel flow. The flows during this small rising tide did not resemble the flows observed on a similar small rising tide on August 19, 1980 (see Figure 6).

Figure 26 presents the salinity distribution throughout the water column in Blair Waterway at the end of the small rising tide. Throughout the entire waterway, the upper 3 m of the water column was less than 28 parts per thousand (ppt) salinity. The isosals (lines of equal salinity) begin to slope downward just west of the 11th Street bridge. The surface water within the middle and inner segments was 21 to 22 ppt. In the outer segment, the Puyallup River plume was evident as a wedge of "fresher" water with the surface salinities decreasing from 22 to 18 ppt at the entrance to the waterway. The 29 ppt isosal varied in depth from 4.5 m in the outer segment to 9 m in the inner segment. The surface flow opposed the rising tide due to winds, as evidenced by the drogue trajectories and current profiles.

2.4.3 Large Falling Tide - February 17, 1981

Figures 18 (O, M, and I) and 19 (O, M, and I) in the appendix present trajectories for drogues at 0.1 m, 0.5 m, 1 m, 2 m, 3 m, 4 m, 6 m, and 10 m for the first and second halves of a large falling tide of 11.9 feet. Tables 2.18 and 2.19 in the appendix present depth, time, location, speed, and direction information on these drogues. Figures 25.18 and 25.19 in the appendix present the longitudinal current profiles. Figure 27 presents the salinity distribution throughout the water column at the end of the falling tide.

Winds during this period decreased to less than 5 kt from the south for most of the falling tide then increased briefly to 11 kt at 2037.

Strong ebb flow persisted in the surface waters throughout the fall of the tide in the inner and middle segments (0.3 to 0.4 kt), while the outer segment experienced weak flood flow (less than 0.1 kt), perhaps driven by winds in Commencement Bay that may have been contrary to the weak southerly winds within the waterway. For the first half of the falling tide, the inner segment ebbed at all depths while flood flow was evident in the middle segment at 2 m and 3 m (0.03 to 0.07 kt) and at the surface and 3 m in the outer segment. In the outer segment, the flood flow was strongest at 6 m and at 2 m. By the last half of the falling tide, ebb flow prevailed at all but 10 m in all segments and was strongest (0.21 kt) between 3 and 4 m in the outer segment. The flow at 1 m was weak in all the segments for the last half of the falling tide. Figure 19-O shows that the 10 m drogue moved cross channel toward the southern shore in the outer segment. In the middle segment (see Figure 19-M), water at 10 m moved in the same direction as the other drogues but more slowly. In the inner segment (see Figure 19-I) 10 m flooded weakly, in opposition to the ebb flow above it.

The flows observed during this large falling tide showed some resemblance to the large falling tide in the summer study (see Figure 7) although the data were largely incomplete for the middle segment during the summer study. The surface flows differed considerably between the summer and winter studies, but this can be attributed to differences in wind.

The salinity distribution (see Figure 27) at the end of the falling tide compared to the salinity distribution before the fall of the tide (see Figure 26) helps to explain the flow of water during the falling tide. Within the middle and inner segments, the surface salinity increased slightly, indicating that the surface waters (upper 0.5 m) had been driven out by the winds and tide and were replaced with water that was at about 1 m at the preceding high tide. In the outer segment, the surface salinities had decreased with the effect of the Puyallup River extending further into the waterway than it did at high tide. This is caused by wind effect on surface waters during the two tides. On the rising tide, the southeast wind opposed the inflow of surface water. On the falling tide, winds from Commencement Bay (although weaker) helped to drive the Puyallup River plume into the waterway partially counteracting the usual effects of a falling tide on surface waters.

The base of the halocline*, as defined by the 28-ppt isosal, remained at 3 m. The volume of water within the waterway that exceeded 29 ppt (represented by the area between the 29-ppt isosal and the bottom) decreased by about 40 percent indicating much of the marine water had left the waterway or mixed with the "fresher" surface water in order to maintain the halocline at 3 m while the surface waters ebbed. Both mechanisms were operational. Drogue movements indicated that the outer segment ebbed strongly at 6 m in the outer segment and the water at this depth was greater than 29 ppt salinity.

2.4.4 Large Rising Tide - February 17 - 18, 1981

Figures 20 (O, M, and I) and 21 (O and M) in the appendix present trajectories for drogues at 0.1 m, 0.5 m, 1 m, 2 m, 3 m, 4 m, 6 m, and 10 m for the first and second halves of a large rising tide of 13.7 feet. Tables 2.20 and 2.21 in the appendix present depth, time, location, speed, and direction information associated with these drogues. Figures 25.20 and 25.21 in the appendix present longitudinal current profiles for this time and Figure 28 presents the salinity distribution throughout the water column at the end of this rising tide.

Winds during this period were about 5 to 10 kt from the south to west-southwest in the middle segment and more westerly to northwesterly in the outer segment. The winds were strongest between 0230 and 0400, with speeds in the middle segment measured at 11 and 12 kt from the southwest.

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*The halocline is the depth range over which the change in salinity is greatest.

The first half of the rising tide showed very strong flood flows at the surface (greater than 0.5 kt) in the middle and outer segments, strong flood flows (greater than 0.2 kt) at 10 m and weaker flood flows at mid-depths of 2 to 4 m (which corresponds to the depth range of the base of the halocline). The flood flow at mid-depth decreased from about 0.1 kt in the outer segment to 0.01 to 0.04 kt in the middle segment and reversed to ebb in the inner segment. The inner segment was not sampled during the last half of the rising tide because of ship movement. However, a reversal to ebb flow was observed in the middle segment by the last half of the rising tide with ebb flow evident at 3 and 4 m, and cross-channel flow only at 6 and 10 m. Figure 21-M illustrates the extent of the cross-channel flows within the middle segment between 0345 and 0456. The winds had developed a surface flow toward the northern shoreline of the waterway and this affected the flow in the entire water column. All drogues from the surface to 6 m flowed toward the northern shore. To compensate for this flow, the water at depth had to flow toward the southern shoreline. The drogue at 10 m confirmed the presence of such a flow.

Water movement observed throughout the waterway during this large rising tide appeared very similar to the flows on the large rising tide of the summer study (see Figure 7). The pattern of flow reversal around 3 m in the inner segment and the inhibition of flood flow at 3 m in the middle or outer segments were also observed in other waterways during flood tides in the summer studies. The current speeds appear comparable to the summer spring tide study (when averaged over the duration of the rising tide). During the summer study, the flood flow at depth was fairly constant for both halves of the rising tide. Conversely, the flood flow was twice as strong on the first half of the rising tide during the winter study and had essentially stopped by the second half of the rising tide.

The salinity distribution at the end of the rising tide indicates quite clearly that the surface water down to 1.5 m was less than 22 ppt (see Figure 28). This in turn indicates that the upper 1.5 m of the water column was totally injected from Commencement Bay and that previous surface water was displaced downward. As a result, the base of the halocline, defined by the 28 ppt isosal, was displaced downward to 4 m. The amount of water present greater than 29 ppt was less than on the previous high tide (see Figure 26) as the surface flow made up a larger portion of the intertidal volume. Surface drogue trajectories clearly showed the extent of the surface inflow and totally support the observed salinity distribution.

2.4.5 Medium Falling Tide - February 18, 1981

Figures 22 (O, M, and I) and 23 (O, M, and I) in the appendix present trajectories for drogues at 0.1 m, 0.5 m, 1 m, 2 m, 3 m, 4 m, 6 m, and 10 m for the first and last halves of a falling tide of 7.1 feet. Tables 2.22 and 2.23 in the appendix present depth, time, location, speed, and direction information associated with these drogues. Figures 25.22 and 25.23 in the appendix present the longitudinal current profiles for this falling tide. This falling tide was 5 feet greater than the summer neap tide study and 3 feet less than the summer time spring tide study. Therefore, it was compared to both summer studies.

Winds during this sampling period were weak (4 to 6 kt) and from the west in the middle segment. During the first half of the falling tide, the water at 6 and 10 m in the outer segment initially was flooding, then curved counterclockwise and began to ebb (see Figure 22-O). The surface waters in all segments of the waterway ebbed strongly (0.2 to 0.3 kt). Bottom water movement was sluggish in the first half and then gradually accelerated to about 0.05 to 0.10 kt. Disregarding the upper 0.5 m, the greatest ebb flow occurred between 2 and 6 m in the inner segment, between 1 and 4 m in the middle segment, and between 1 and 3 m in the outer segment (see Figures 25.22 and 25.23). This pattern was identical to that observed in both the summer studies. Speeds obtained were less than for the larger falling tide in the summer study and more than that observed for the smaller falling tide. This pattern was similar on the larger falling tide during the winter study (see Figures 25.18 and 25.19).

2.4.6 Small Rising Tide - February 18, 1981

Figure 24 (O and M) in the appendix presents trajectories for drogues at 0.1 m, 1 m, 2 m, 3 m, 4 m, 6 m, and 10 m for the first half of a rising tide of 5.2 feet. Table 2.24 in the appendix presents depth, time, location, speed, and direction information associated with these drogues. Figure 25.24 in the appendix presents the longitudinal current profiles. The inner segment was not sampled during this cycle due to vessel traffic in the waterway.

The outer segment flooded at the surface at 0.3 kt and at the bottom (0.08 kt) while the drogues at 2 and 3 m continued to ebb at greater than 0.1 kt. This ebb flow at 2 and 3 m was a continuation of the strong ebb flow at that depth on the previous falling tide. It was evident in Figure 7 that this depth also resisted flood flow on a large rising tide in the outer segment in the summer study. The middle segment exhibited flood flow at all but 6 m; however, much of the drogue movement at this time was cross channel (see Figure 24-M).

2.4.7 Current Meter Observations

Current meters were also used to measure currents from a moored vessel in the middle segment in the winter study (see Table 3). Longitudinal current profiles were constructed from the current meter data, averaged for the same time periods as the drogue deployments in the middle segment, and compared with the drogue-derived profiles. The degree of agreement varied widely. This variance was due to the different sampling characteristics of current meters vs. drogues. The current meter is used to measure current past a single point, whereas drogues measure water movement over a depth range of 0.2 to 1 m (depending on drogue design) and follow a parcel of water. Where eddy flow exists, such motion may or may not be detected with one or the other method and differences in sampling methods will produce differences in values obtained.

Interpretations of current data must reflect the differences in measurement techniques and not seek to represent more than the techniques permit. Drogue observations were not continuous, which resulted in some anomalies. For example, scientists on the moored vessel observed a drogue launched in the middle segment move counterclockwise in a broad circle around the moored vessel. By the time the drogue chase boat returned to make its observation, this drogue was near its original position. Point-to-point plotting of the drogue fixes failed to show this eddy effect. From the moored vessel, other drogues were observed which ebbed with a meandering motion from one side of the waterway to the other; yet when observations were made by scientists in the chase boat, the drogue appeared to remain near the center of the waterway.

2.4.8 Water Characteristics

Personnel on the moored vessel collected discrete water samples at four depths at about 4-hour intervals. Temperatures were obtained using reversing thermometers and samples were drawn for salinity and dissolved oxygen. These samples were preserved for later analysis by the University of Washington Department of Oceanography. The data for these samples are presented in Table 4. Values of depth are recorded in meters below the surface, temperature in degrees celsius, salinity in parts per thousand, density as sigma-t, oxygen in milligram atoms per liter, and oxygen saturation in percent. To obtain oxygen values in milligrams per liter, multiply the reported values by 16.0.

In addition to these discrete water samples, an InterOcean salinity-temperature-depth probe was used to measure the temperature and salinity at closely spaced depth intervals and at several locations along the length of the waterway. These data are presented in Table 5 using the same units as described above. The sample locations for each series are shown in Figures 26, 27, and 28.

TABLE 4

WATER SAMPLES OBTAINED IN THE MIDDLE OF BLAIR WATERWAY[(a)]

WATER SAMPLES
DATE: 17 Feb 81 TIME: 1315-1334 STATION: 5

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.86	22.63	17.38	0.556	78
3.0	9.33	27.53	21.26	0.460	66
6.0	9.22	28.86	22.31	0.453	65
10.0	9.25	29.15	22.53	0.450	65

WATER SAMPLES
DATE: 17 Feb 81 TIME: 1702-1722 STATION: 5

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.87	23.14	17.77	0.551	78
3.0	9.46	27.33	21.09	0.468	67
6.0	9.20	29.06	22.47	-	-
10.0	9.26	29.21	22.58	0.454	65

WATER SAMPLES
DATE: 17 Feb 81 TIME: 2001-2019 STATION: 5

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.85	22.53	17.30	0.511	72
3.0	9.35	27.74	21.42	0.464	66
6.0	9.29	28.63	22.12	0.453	65
10.0	9.21	29.22	22.60	0.448	65

WATER SAMPLES
DATE: 17 Feb 81 TIME: 2332-2349 STATION: 5

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.55	21.92	16.87	0.536	75
3.0	9.33	27.01	20.86	0.476	68
6.0	9.22	28.48	22.02	0.452	65
10.0	9.20	29.15	22.54	0.449	65

WATER SAMPLES
DATE: 18 Feb 81 TIME: 0321-0338 STATION: 5

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.43	19.71	15.17	0.566	78
3.0	9.34	27.49	21.23	0.476	68
6.0	9.28	28.57	22.08	0.455	65
10.0	9.25	29.04	22.45	0.453	65

WATER SAMPLES
DATE: 18 Feb 81 TIME: 0644-0700 STATION: 5

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.45	20.72	15.95	0.615	85
3.0	9.34	26.63	20.56	0.468	67
6.0	9.25	28.43	21.97	0.456	65
10.0	9.23	28.90	22.34	0.466	67

WATER SAMPLES
DATE: 18 Feb 81 TIME: 1221-1235 STATION: 5

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.59	20.20	15.53	0.549	76
3.0	9.41	27.01	20.85	0.472	67
6.0	9.31	28.39	21.93	0.465	67
10.0	9.27	28.95	22.38	0.456	67

WATER SAMPLES
DATE: 18 Feb 81 TIME: 1258-1312 STATION: 8

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.55	20.96	16.13	0.504	70
3.0	9.41	24.58	18.96	0.483	68
6.0	9.29	28.56	22.07	0.441	63
10.0	9.33	28.77	22.23	0.438	63

(a) [illegible] To obtain oxygen values in milligrams per liter, multiply the reported

TABLE 4 (continued)

WATER SAMPLES
DATE: 18 Feb 81 TIME: 1327-1338 STATION: 2

Depth	Temp.	Sal.	Den.	Oxygen	Sat.
1.0	9.12	15.92	12.26	0.601	80
3.0	9.08	26.77	20.71	0.504	71
6.0	9.19	28.80	22.27	0.463	66
10.0	9.17	29.21	22.59	0.465	67

TABLE 5 Sheet 1 of 5

CONTINUOUS MEASUREMENTS OF TEMPERATURE AND SALINITY
ALONG THE LONGITUDINAL AXIS OF BLAIR WATERWAY
(Units explained in text)

DATE: 17 Feb 81 TIME: 1140
STATION: 5

Depth	Temp.	Sal.	Den.
0.9	9.58	22.62	17.41
1.5	9.65	23.53	18.11
2.8	9.52	27.21	20.99
4.3	9.45	28.48	21.98
5.6	9.40	28.77	22.22
6.6	9.40	28.87	22.29
7.5	9.38	28.99	22.39
8.7	9.38	29.02	22.41
9.8	9.38	29.04	22.43
11.0	9.20	29.07	22.48
12.2	9.19	29.09	22.50
13.9	9.18	29.18	22.57
14.9	9.18	29.22	22.60

DATE: 17 Feb 81 TIME: 1420-1428
STATION: 8

Depth	Temp.	Sal.	Den.
0.4	9.72	22.69	17.45
1.5	9.58	24.95	19.22
2.3	9.55	26.01	20.05
3.0	9.51	27.53	21.24
3.8	9.43	28.58	22.06
4.9	9.42	29.86	23.06
6.0	9.41	28.92	22.33
7.1	9.40	28.97	22.37
8.4	9.40	29.01	22.40
9.4	9.26	29.05	22.46
10.6	9.24	29.06	22.47
11.8	9.22	29.08	22.48
14.8	9.22	29.12	22.52
15.6	9.26	29.12	22.51

DATE: 17 Feb 81 TIME: 1435-1446
STATION: 7

Depth	Temp.	Sal.	Den.
0.4	9.76	21.34	16.39
1.6	9.59	26.35	20.31
2.2	9.53	27.31	21.06
2.9	9.51	27.90	21.52
3.9	9.45	28.42	21.94
5.0	9.43	28.67	22.13
6.0	9.41	28.86	22.28
7.0	9.41	28.96	22.36
8.5	9.42	29.02	22.41
8.8	9.40	29.03	22.42
8.2	9.26	29.00	22.42
9.7	9.23	29.04	22.45
11.9	9.22	29.07	22.48
13.8	9.22	29.10	22.50
15.8	9.21	29.13	22.53
17.1	9.20	29.30	22.69

DATE: 17 Feb 81 TIME: 1450-1457
STATION: 6

Depth	Temp.	Sal.	Den.
0.4	9.83	22.70	17.44
1.8	9.67	25.34	19.51
2.8	9.55	27.90	21.52
3.8	9.47	28.59	22.07
4.6	9.45	29.73	22.96
5.8	9.32	28.85	22.29
7.0	9.30	28.90	22.33
8.0	9.32	28.96	22.38
9.0	9.29	28.97	22.39
10.0	9.28	29.02	22.43
11.0	9.26	29.06	22.46
12.2	9.25	29.08	22.48
13.3	9.25	29.10	22.50
14.3	9.24	29.12	22.51
15.2	9.24	29.13	22.52

TABLE 5

Sheet 2 of 5

DATE: 17 Feb 81 TIME: 1502-1510
STATION: 5

Depth	Temp.	Sal.	Den.
0.3	9.85	21.58	16.57
1.3	9.80	23.37	17.96
2.2	9.60	26.97	20.79
3.3	9.54	28.10	21.67
4.3	9.48	28.64	22.10
5.2	9.35	28.93	22.35
6.3	9.34	29.03	22.47
7.4	9.45	29.04	22.42
8.4	9.32	29.04	22.44
9.4	9.34	29.06	22.45
10.7	9.35	29.10	22.48
11.5	9.24	29.10	22.50
12.5	9.24	29.17	22.55
13.6	9.24	29.18	22.56
14.5	9.23	29.18	22.56
15.6	9.23	29.18	22.56

DATE: 17 Feb 81 TIME: 1517-1524
STATION: 4

Depth	Temp.	Sal.	Den.
0.4	9.87	22.70	17.43
1.2	9.75	24.73	19.02
1.8	9.72	26.05	20.05
2.8	9.48	28.06	21.65
3.8	9.43	28.65	22.12
4.8	9.43	29.01	22.40
5.8	9.32	29.08	22.47
6.8	9.33	29.11	22.49
7.8	9.29	29.16	22.54
8.8	9.28	29.21	22.58
9.8	9.28	29.25	22.61
10.8	9.28	29.24	22.60
11.8	9.27	29.24	22.60
12.8	9.28	29.26	22.62
13.8	9.28	29.26	22.62
14.8	9.28	29.27	22.62

DATE: 17 Feb 81 TIME: 1527-1534
STATION: 3

Depth	Temp.	Sal.	Den.
0.4	9.89	21.71	16.66
1.2	9.75	23.98	18.44
1.8	9.64	26.33	20.28
2.8	9.42	28.70	22.16
3.8	9.43	28.92	22.33
4.8	9.43	29.08	22.45
5.8	9.34	29.08	22.47
6.8	9.38	29.08	22.46
7.8	9.38	29.08	22.46
8.8	9.35	29.11	22.49
9.8	9.34	29.21	22.57
10.8	9.34	29.24	22.59
11.8	9.34	29.25	22.60
12.8	9.34	29.27	22.61
13.8	9.36	29.28	22.62
14.7	9.32	29.27	22.62

DATE: 17 Feb 81 TIME: 1541-1546
STATION: 2

Depth	Temp.	Sal.	Den.
0.3	9.52	18.90	14.53
1.2	9.72	20.66	15.87
1.8	9.86	26.75	20.58
2.5	9.53	28.40	21.91
3.3	9.49	28.81	22.26
4.3	9.40	28.82	22.26
5.8	9.37	29.05	22.44
6.8	9.36	29.09	22.47
8.7	9.36	29.18	22.54
9.9	9.37	29.23	22.58
11.6	9.40	29.31	22.64
13.6	9.42	29.32	22.64
15.8	9.52	29.33	22.63

TABLE 5

Sheet 3 of 5

DATE: 17 Feb 81 TIME: 1548-1553

STATION: 1

Depth	Temp.	Sal.	Den.
0.5	9.27	16.86	12.98
1.8	9.52	19.90	15.31
2.7	9.54	28.72	22.16
3.8	9.52	29.04	22.41
4.8	9.43	29.12	22.48
6.6	9.39	29.19	22.54
8.7	9.40	29.25	22.59
10.8	9.40	29.32	22.64
12.8	9.42	29.35	22.66
14.7	9.43	29.35	22.66
16.8	9.44	29.36	22.67

DATE: 17 Feb 81 TIME: 2147

STATION: 2

Depth	Temp.	Sal.	Den.
0.2	9.50	14.97	11.48
1.1	9.50	17.30	13.29
1.8	9.50	25.30	19.50
2.8	9.50	27.69	21.36
3.8	9.50	28.87	22.28
4.8	9.40	29.02	22.41
6.8	9.40	29.10	22.47
8.8	9.40	29.15	22.51
10.8	9.40	29.26	22.60

DATE: 17 Feb 81 TIME: 2207-2212

STATION: 4

Depth	Temp.	Sal.	Den.
0.3	9.50	22.60	17.41
1.2	9.50	23.02	17.73
1.8	9.50	24.55	18.92
2.8	9.50	28.13	21.70
4.8	9.40	28.81	22.25
6.8	9.40	28.97	22.37
8.8	9.40	29.06	22.44
11.0	9.40	29.14	22.50

DATE: 17 Feb 81 TIME: 2225-2229

STATION: 6

Depth	Temp.	Sal.	Den.
0.3	9.50	24.16	18.62
1.2	9.50	25.77	19.87
1.8	9.50	27.02	20.84
2.8	9.50	27.90	21.52
3.8	9.50	28.46	21.96
4.8	9.40	28.62	22.10
5.8	9.40	28.78	22.22
7.3	9.40	28.91	22.33
9.3	9.40	29.10	22.47
11.3	9.40	29.15	22.51

TABLE 5

DATE: 17 Feb 81 TIME: 2230-2235

STATION: 8

Depth	Temp.	Sal.	Den.
0.2	9.50	23.98	18.48
1.1	9.50	26.91	20.75
2.2	9.50	27.66	21.34
3.1	9.50	28.20	21.76
4.7	9.40	28.59	22.08
6.7	9.40	29.87	23.07
8.7	9.40	29.03	22.42
10.6	9.40	29.08	22.46
11.8	9.40	29.08	22.46

DATE: 18 Feb 81 TIME: 0723-0727

STATION: 2

Depth	Temp.	Sal.	Den.
0.2	9.50	17.23	13.24
1.2	9.50	19.10	14.69
1.8	9.50	26.97	20.80
3.8	9.50	29.84	23.03
5.8	9.50	28.96	22.35
7.8	9.40	29.05	22.43
9.8	9.40	29.08	22.46
11.9	9.40	29.09	22.47
13.8	9.40	29.11	22.48
16.0	9.40	29.16	22.52

DATE: 18 Feb 81 TIME: 0738-0743

STATION: 4

Depth	Temp.	Sal.	Den.
0.2	9.50	19.03	14.63
1.2	9.50	19.90	15.31
1.9	9.50	25.02	19.29
2.8	9.50	27.45	21.17
4.8	9.50	28.63	22.09
6.8	9.40	28.92	22.33
8.8	9.40	29.03	22.42
10.8	9.40	29.06	22.44
12.8	9.40	29.11	22.48
14.8	9.40	29.14	22.50

DATE: 18 Feb 81 TIME: 0751-0755

STATION: 6

Depth	Temp.	Sal.	Den.
0.2	9.50	18.45	14.18
1.2	9.50	23.16	17.84
2.1	9.50	25.10	19.35
3.8	9.50	27.83	21.47
5.8	9.40	28.70	22.16
7.8	9.40	28.83	22.26
9.8	9.40	28.94	22.35
11.8	9.40	29.02	22.41
14.1	9.40	29.15	22.51

TABLE 5

DATE: 18 Feb 81 TIME: 0804-0808

STATION: 8

Depth	Temp.	Sal.	Den.
0.2	9.50	19.29	14.84
1.1	9.50	21.71	16.72
2.1	9.50	25.46	19.63
3.7	9.50	28.21	21.77
5.9	9.40	29.88	23.08
11.5	9.40	29.06	22.44
11.8	9.40	29.10	22.47
15.3	9.40	29.15	22.51

3.0 WATER REPLACEMENT - WATERWAYS

3.1 *INTRODUCTION*

The intent of the water replacement analysis presented in this section was to compute the flushing times of six of the waterways at the head of Commencement Bay, utilizing an approximate first-order technique. The six waterways selected were, from south to north, City Waterway, Middle Waterway, Milwaukee Waterway, Sitcum Waterway, Blair Waterway, and Hylebos Waterway. Data utilized in this analysis were surface area, depth, and tidal height information taken from NOS Chart No. 18453 of Tacoma Harbor. The analysis was approximate in that water replacement times resulting from the influence of the diurnal component of the tides were calculated without consideration for the intricate circulation patterns within the waterways as discussed in Section 2 of this report. Wind effects and the influence of the Puyallup River outflow were not incorporated in this water replacement analysis and these factors influence circulation patterns.

3.2 METHODS

The analysis of the water replacement times in the six waterways consisted of two types of calculations. First, it was necessary to estimate the volumes of each of the waterways, both at mean higher high water (MHHW) and at mean lower low water (MLLW). MHHW is defined as being +11.8 feet above MLLW. MLLW is defined as being a water surface elevation of 0.0 feet or the datum of soundings. There was a problem in the use of MHHW and MLLW in that while the MLLW line is clearly indicated on the chart, the mean high water line (MHW), rather than the MHHW line, is used to indicate the upland-intertidal boundary. The use of volumes at both MHHW and MLLW is needed, however, to accurately calculate water replacement times resulting from the diurnal component of the tide. Conversely, the use of MHW and mean low water (MLW) volumes is required to estimate water replacement times resulting from the semidiurnal component of the tide. However, the MLW line, like the MHHW line, is also not indicated on the chart. These issues were resolved by applying the following considerations: (1) over a major portion of the area considered, the shoreline is modified (steep bank) so that the increase in surface area in going from MHW to MHHW is negligible and would not result in an appreciable error; and (2) the use of just the diurnal replacement times results in a more conservative estimate of flushing times as compared to the use of semidiurnal replacement times.

Volume estimates for each of the waterways were calculated by obtaining average depth estimates over various segments of the waterways and multiplying these by the surface area of the respective segments. Average depth estimates were calculated by using the cross sections illustrated in Figures 29 through 34. Each cross section was divided into a number of parts, depending on the width of the cross sections. The depths in each part were averaged to give a representative average depth for each waterway segment. The surface area of each segment was calculated using a compensating polar planimeter. A listing of average depths as calculated are in Table 6, surface area calculations are in Table 7, and volume calculations are in Table 8.

The second type of calculation involved the use of volume estimates in each waterway for an analysis of the water replacement times by two different methods used by Collias and Loehr (1974). The first method assumed that: (1) there was zero mixing between the incoming and outgoing waters; (2) incoming waters totally replaced basin water in amounts equivalent to the intertidal volume; and (3) there was no refluxing (return) of water that exited the system on an ebb tide. The first assumption is clearly not realistic in the present situation. There will always be some mixing of incoming water with the basin waters. The third assumption may not be realistic in some of the waterways, particularly Blair and Hylebos, where tidal excursion distances may not be as great as the length of the waterways and complicated circulation patterns result in significant refluxing. The flushing rate in tidal days (t) (where one tidal day is equal to 24.84 hours) to replace a given fraction of basin water is as follows:

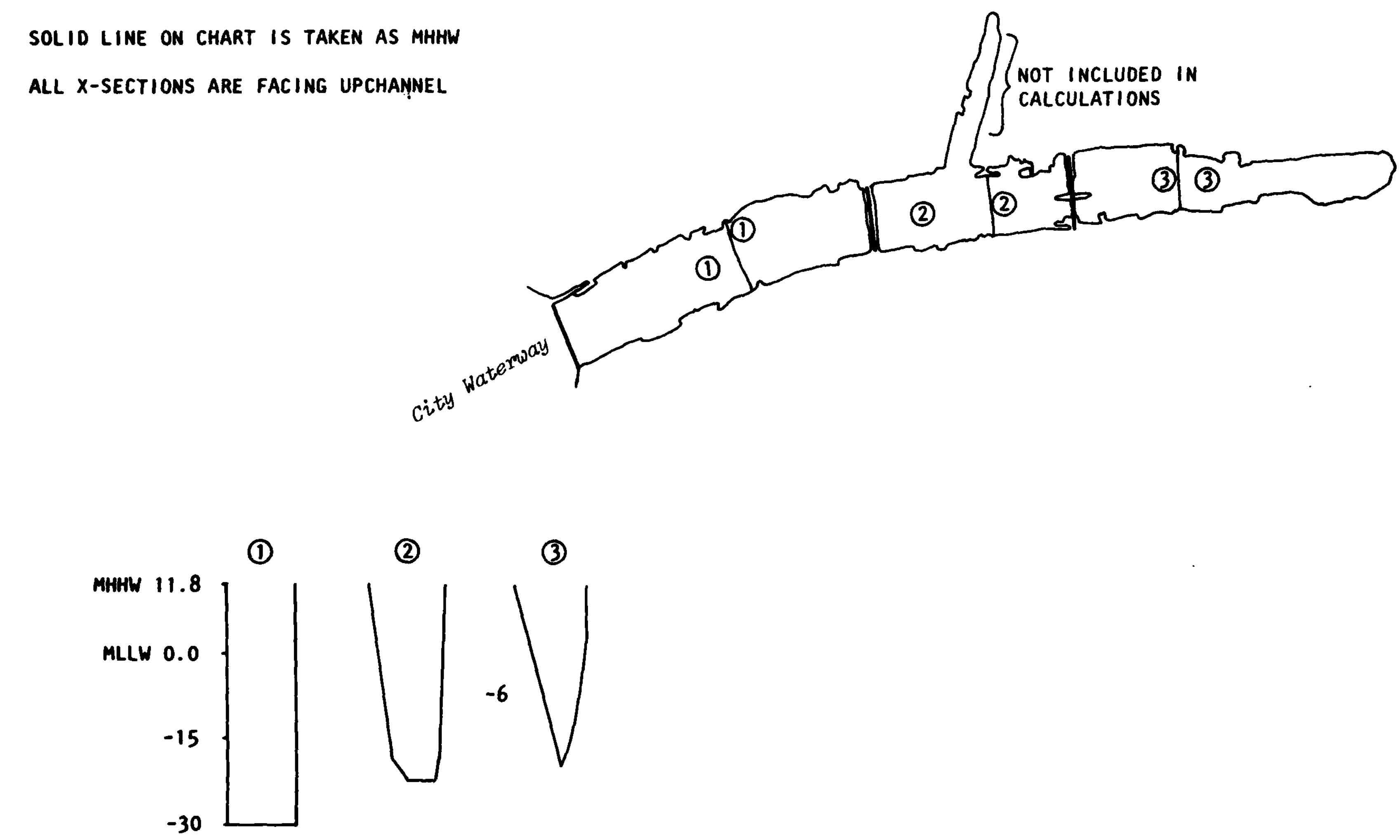


Figure 29
PLAN VIEW AND SELECTED CROSS SECTIONS IN CITY WATERWAY

SOLID LINE ON CHART IS TAKEN AS MHHW

ALL X-SECTIONS ARE FACING UPCHANNEL

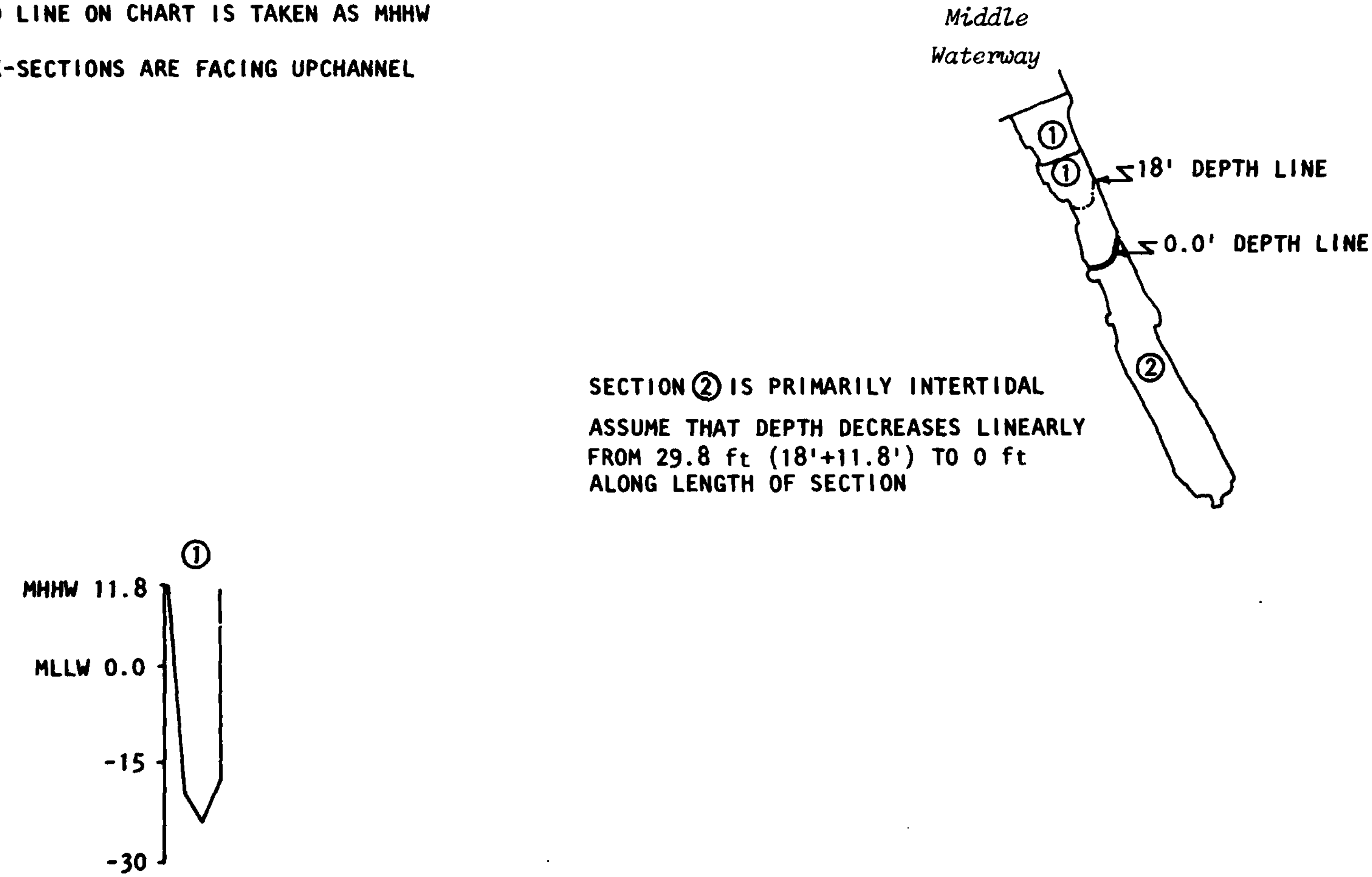
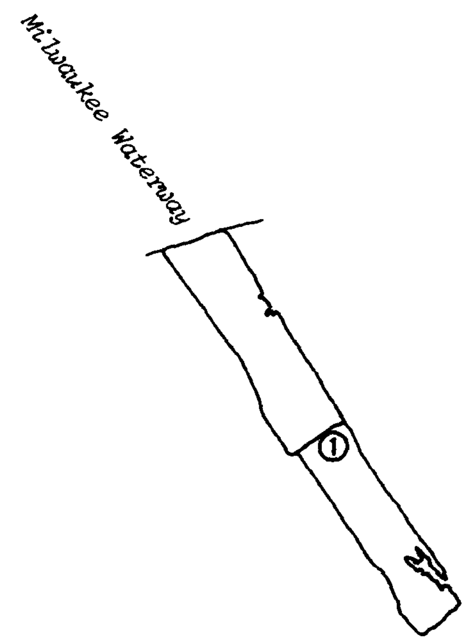


Figure 30
PLAN VIEW AND SELECTED CROSS SECTIONS IN MIDDLE WATERWAY

SOLID LINE ON CHART IS TAKEN AS MHHW

ALL X-SECTIONS ARE FACING UPCHANNEL



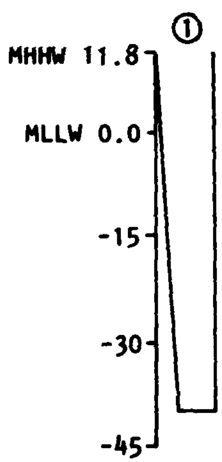


FIGURE 31
PLAN VIEW AND SELECTED CROSS SECTIONS IN MILWAUKEE WATERWAY

SOLID LINE ON CHART IS TAKEN AS MHHW

ALL X-SECTIONS ARE FACING UPCHANNEL

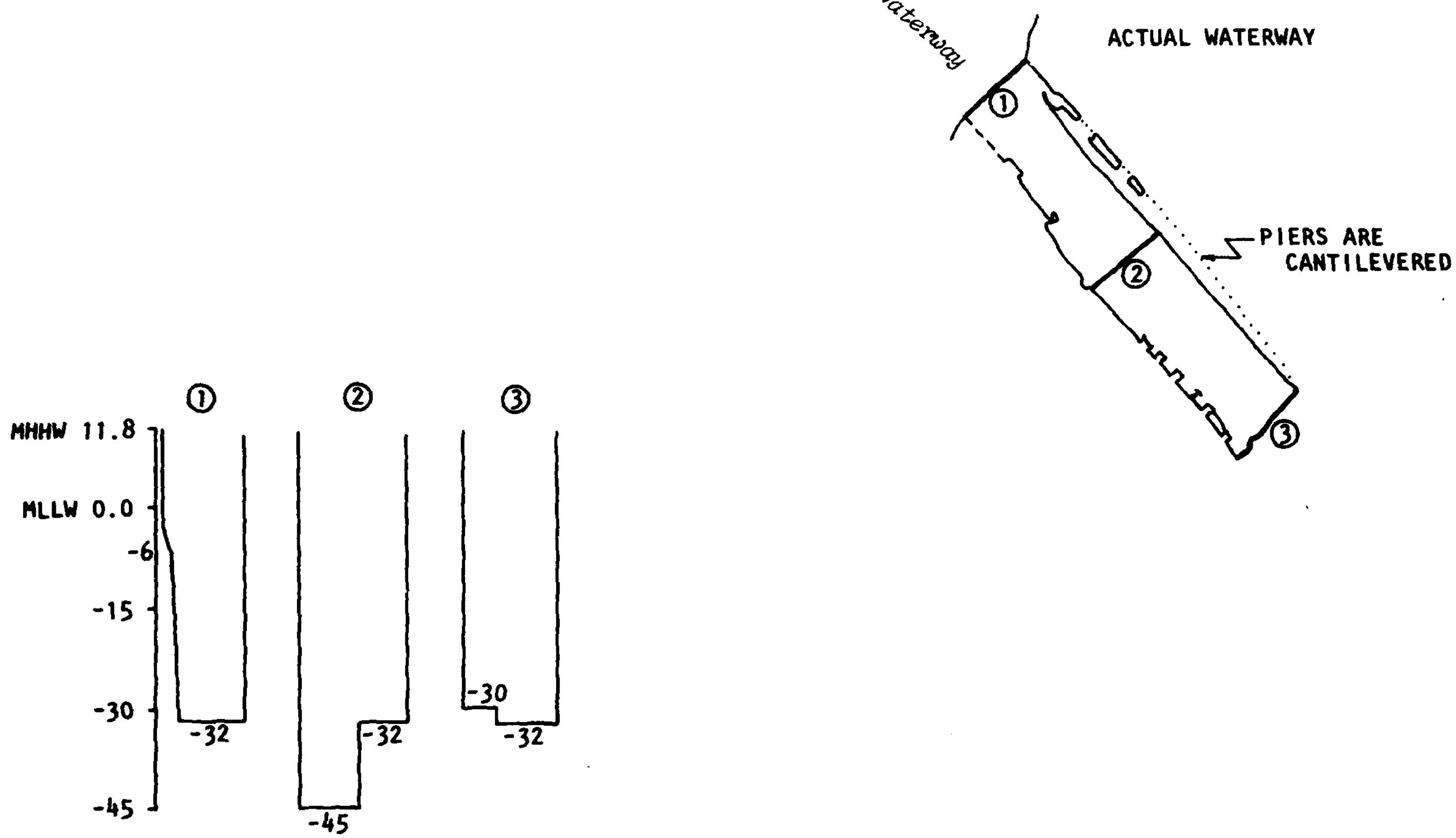


Figure 32
PLAN AND VIEW SELECTED CROSS SECTIONS IN SITCUM WATERWAY

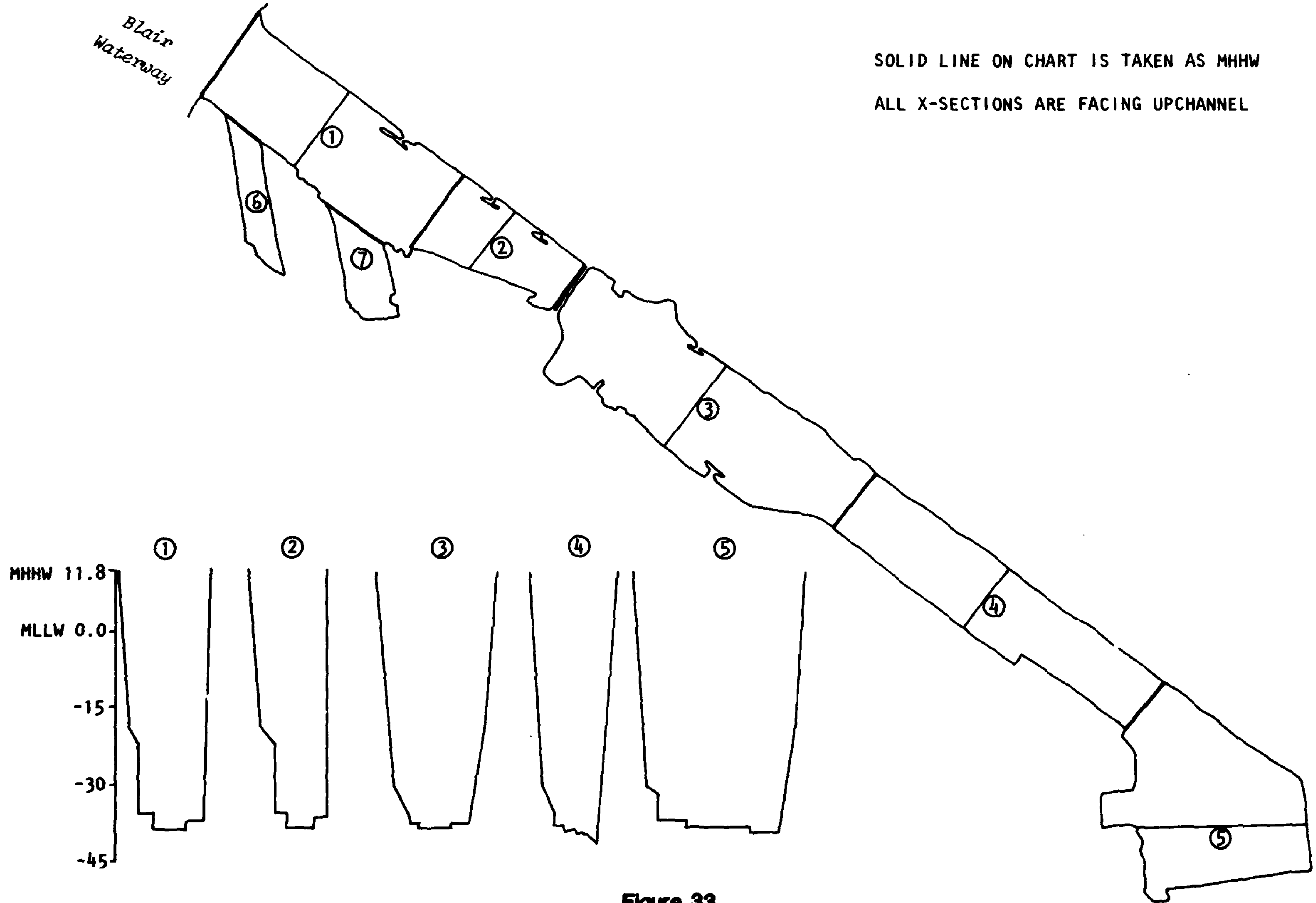


Figure 33
PLAN VIEW AND SELECTED CROSS SECTIONS IN BLAIR WATERWAY

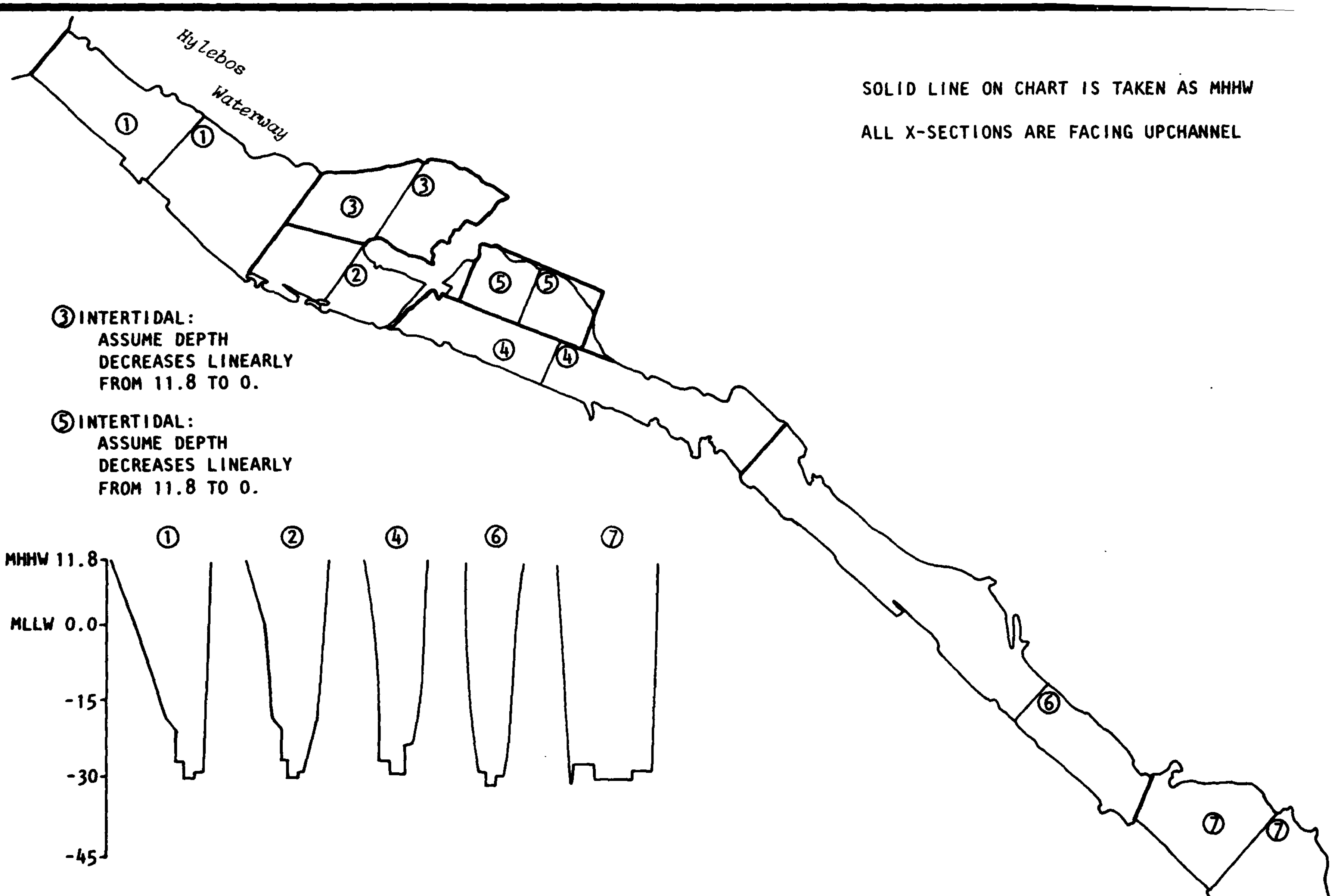


Figure 34
PLAN VIEW AND SELECTED CROSS SECTIONS IN HYLEBOS WATERWAY

TABLE 6

AVERAGE DEPTH CALCULATIONS OF WATERWAYS

	d_{MHHW}(ft)	d_{MLLW}(ft)
1. City Waterway		
Section 1	41.8	30
Section 2	28.3	16.5
Section 3	20	8.2
2. Middle Waterway		
Section 1	30.5	18.7
Section 2	See Chart 18453, Figure 2, and Table 3	
3. Milwaukee Waterway		
Section 1	46.0	34.2
4. Sitcum Waterway		
Section 1	45.7	33.9
5. Blair Waterway		
Section 1	45.9	34.1
Section 2	41.9	30.1
Section 3	42.3	30.5
Section 4	42.7	30.9
Section 5	45.8	34.0
Section 6, Section 7†	See Chart 18453, Figure 5, and Table 3	
6. Hylebos Waterway		
Section 1	25.2	13.4
Section 2	29.0	17.2
Section 3	See Chart 18453, Figure 6, and Table 3	
Section 4	31.2	19.4
Section 5	See Chart 18453, Figure 6, and Table 3	
Section 6	36.4	24.6
Section 7	38.9	27.1

TABLE 7

SURFACE AREA MEASUREMENTS OF WATERWAYS

	ft^2
1. City Waterway	
Section 1	1.848×10^6
Section 2	1.121×10^6
Section 3	1.242×10^6
2. Middle Waterway	
Section 1	0.227×10^6
Section 2	$0.667 \times 10^6 = A_2$
	$0.136 \times 10^6 = A_2 1$
3. Milwaukee Waterway	
Section 1	1.152×10^6
4. Sitcum Waterway	
Section 1	2.242×10^6
5. Blair Waterway	
Section 1	2.258×10^6
Section 2	1.000×10^6
Section 3	3.242×10^6
Section 4	2.182×10^6
Section 5	2.591×10^6
Section 6	0.455×10^6
Section 7	0.545×10^6
6. Hylebos Waterway	
Section 1	$2.258 \times 10^6 = A_2$
	$1.773 \times 10^6 = A_2 1$
Section 2	0.924×10^6
Section 3	1.242×10^6
Section 4	1.682×10^6
Section 5	0.712×10^6
Section 6	2.576×10^6
Section 7	1.803×10^6

TABLE 8

VOLUME CALCULATIONS OF WATERWAYS

1. City Waterway

Section 1 - Entrance to S. 11th Street Bridge

$A_1 = 1.848 \times 10^6 \ ft^2$
$d_{MHHW} = 30' + 11.8' = 41.8 \ ft$
$d_{MLLW} = 30 \ ft$
$V_{1MHHW} = (A_1)(d_{MHHW}) = 7.724 \times 10^7 \ ft^3$
$V_{1MLLW} = (A_1)(d_{MLLW}) = 5.544 \times 10^7 \ ft^3$

Section 2 - S. 11th Street Bridge to Railroad Bridge

$A_2 = 1.121 \times 10^6 \ ft^2$
$d_{MHHW} = 28.3 \ ft$
$d_{MLLW} = 16.5 \ ft$
$V_{2MHHW} = (A_2)(d_{MHHW}) = 3.172 \times 10^7 \ ft^3$
$V_{2MLLW} = (A_2)(d_{MLLW}) = 1.850 \times 10^7 \ ft^3$

Section 3 - Railroad Bridge to End

$A_3 = 1.242 \times 10^6 \ ft^2$
$d_{MHHW} = 20 \ ft$
$d_{MLLW} = 8.2 \ ft$
$V_{3MHHW} = (A_3)(d_{MHHW}) = 2.484 \times 10^7 \ ft^3$
$V_{3MLLW} = (A_3)(d_{MLLW}) = 1.018 \times 10^7 \ ft^3$

$V_T = V_1 + V_2 + V_3$
$V_{TMHHW} = 13.380 \times 10^7 \ ft^3$
$V_{TMLLW} = 8.412 \times 10^7 \ ft^3$

2. Middle Waterway

Section 1 - Entrance to 18' Depth Contour

$A_1 = 0.227 \times 10^6 \ ft^2$
$d_{MHHW} = 30.5 \ ft$
$d_{MLLW} = 18.7 \ ft$
$V_{1MHHW} = (A_1)(d_{MHHW}) = 6.924 \times 10^6 \ ft^3$
$V_{1MLLW} = (A_1)(d_{MLLW}) = 4.245 \times 10^6 \ ft^3$

Section 2 - 18' Depth Contour to End

$A_2 = 0.667 \times 10^6 \ ft^2$
$A_2 1$ = surface area from 18' contour to 0.0' contour $= 0.136 \times 10^6 \ ft^3$
- depth is considered to decrease linearly from 18' below MLLW to 11.8' above MLLW.

$d_{MHHW} = 29.8 \ ft$
$d_{MLLW} = 18 \ ft$
$V_{2MHHW} = (1/2)(A_2)(d_{MHHW}) = 9.938 \times 10^6 \ ft^3$
$V_{2MLLW} = (1/2)(A_2)(d_{MLLW}) = 1.224 \times 10^6 \ ft^3$

$V_T = V_1 + V_2$
$V_{TMHHW} = 16.862 \times 10^6 \ ft^3$
$V_{TMLLW} = 5.469 \times 10^6 \ ft^3$

TABLE 8 (Continued)

3. Milwaukee Waterway

Section 1 - Entire Waterway

$A_1 = 1.152 \times 10^6$ ft^2
$d_{MHHW} = 46.0$ ft
$d_{MLLW} = 34.2$ ft
$V_{1MHHW} = (A_1)(d_{MHHW}) = 5.299 \times 10^7$ ft^3
$V_{1MLLW} = (A_1)(d_{MLLW}) = 3.940 \times 10^7$ ft^3

$V_T = V_1$
$V_{TMHHW} = 5.299 \times 10^7$ ft^3
$V_{TMLLW} = 3.940 \times 10^7$ ft^3

4. Sitcum Waterway

Section 1 - Entire Waterway

$A_1 = 2.242 \times 10^6$ ft^2
$d_{MHHW} = 45.7$ ft
$d_{MLLW} = 33.9$ ft
$V_{1MHHW} = (A_1)(d_{MHHW}) = 1.025 \times 10^8$ ft^3
$V_{1MLLW} = (A_1)(d_{MLLW}) = 7.600 \times 10^7$ ft^3

$V_T = V_1$
$V_{TMHHW} = 1.025 \times 10^8$ ft^3
$V_{TMLLW} = 0.760 \times 10^8$ ft^3

5. Blair Waterway

Section 1 - Entrance to First Channel Narrowing

$A_1 = 2.258 \times 10^6$ ft^2
$d_{MHHW} = 45.9$ ft
$d_{MLLW} = 34.1$ ft
$V_{1MHHW} = (A_1)(d_{MHHW}) = 1.036 \times 10^8$ ft^3
$V_{1MLLW} = (A_1)(d_{MLLW}) = 7.770 \times 10^7$ ft^3

Section 2 - First Channel Narrowing to E. 11th Street Bridge

$A_2 = 1.000 \times 10^6$ ft^2
$d_{MHHW} = 41.9$ ft
$d_{MLLW} = 30.1$ ft
$V_{2MHHW} = (A_2)(d_{MHHW}) = 4.19 \times 10^7$ ft^3
$V_{2MLLW} = (A_2)(d_{MLLW}) = 3.01 \times 10^7$ ft^3

Section 3 - E. 11th Street Bridge to Lincoln Avenue

$A_3 = 3.242 \times 10^6$ ft^2
$d_{MHHW} = 42.3$ ft
$d_{MLLW} = 30.5$ ft
$V_{3MHHW} = (A_3)(d_{MHHW}) = 1.371 \times 10^8$ ft^3
$V_{3MLLW} = (A_3)(d_{MLLW}) = 9.888 \times 10^7$ ft^3

5. Blair Waterway (Continued)

Section 4 - Lincoln Avenue to Turning Basin

$A_4 = 2.182 \times 10^6\ ft^2$
$d_{MHHW} = 42.7\ ft$
$d_{MLLW} = 30.9\ ft$
$V_{4MHHW} = (A_4)\ (d_{MHHW}) = 9.317 \times 10^7\ ft^3$
$V_{4MLLW} = (A_4)\ (d_{MLLW}) = 6.742 \times 10^7\ ft^3$

Section 5 - Turning Basin

$A_5 = 2.591 \times 10^6\ ft^2$
$d_{MHHW} = 45.8\ ft$
$d_{MLLW} = 34.0\ ft$
$V_{5MHHW} = (A_5)\ (d_{MHHW}) = 1.187 \times 10^8\ ft^3$
$V_{5MLLW} = (A_5)\ (d_{MLLW}) = 8.809 \times 10^7\ ft^3$

Section 6 - Western Ship Basin

$A_6 = 0.455 \times 10^6\ ft^2$
$d_{MHHW} = 42.8\ ft$
$d_{MLLW} = 31\ ft$
$V_{6MHHW} = (0.9\ A_6)\ (42.8\ ft) + (0.1\ A_6)\ (13.8\ ft) = 1.81545 \times 10^7\ ft^3$
$V_{6MLLW} = (0.9\ A_6)\ (31\ ft) + (0.1\ A_6)\ (2\ ft) = 1.279 \times 10^7\ ft^3$

Section 7 - Eastern Ship Basin

$A_7 = 0.545 \times 10^6\ ft^2$
$d_{MHHW} = 25.8\ ft$ see Chart 18453
$d_{MLLW} = 14\ ft$
$V_{7MHHW} = (A_7)\ (d_{MHHW}) = 1.406 \times 10^7\ ft^3$
$V_{7MLLW} = (A_7)\ (d_{MLLW}) = 7.63 \times 10^6\ ft^3$

$V_T = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7$
$V_{TMHHW} = 52.67 \times 10^7\ ft^3$
$V_{TMLLW} = 38.19 \times 10^7\ ft^3$

6. Hylebos Waterway

Section 1 - Entrance to First Channel Bend

$A_1 = 2.258 \times 10^6\ ft^2$
$d_{MHHW} = 25.2\ ft$
$d_{MLLW} = 13.4\ ft$
$V_{1MHHW} = (A_1)\ (d_{MHHW}) = 5.690 \times 10^7\ ft^3$
$V_{1MLLW} = (A_1)\ (d_{MLLW}) = 2.376 \times 10^7\ ft^3$

Section 2 - First Channel Bend to E. 11th Street Bridge

$A_2 = 0.924 \times 10^6\ ft^2$
$d_{MHHW} = 29.0\ ft$
$d_{MLLW} = 17.2\ ft$
$V_{2MHHW} = (A_2)\ (d_{MHHW}) = 2.680 \times 10^7\ ft^3$
$V_{2MLLW} = (A_2)\ (d_{MLLW}) = 1.589 \times 10^7\ ft^3$

TABLE 8 (Continued)

6. Hylebos Waterway (Continued)

Section 3 - Intertidal Area North of Section 2

$A_3 = 1.242 \times 10^6\ ft^2$

$d_{MHHW} = 11.8\ ft$ Depth is assumed to decrease linearly from 11.8' to 0'

$d_{MLLW} = 0\ ft$ Not average depths

$V_{3MHHW} = (1/2)\ (A_3)\ (11.8\ ft) = 7.328 \times 10^6\ ft^3$

$V_{3MLLW} = 0\ ft^3$

Section 4 - East 11th Street Bridge to Lincoln Avenue

$A_4 = 1.682 \times 10^6\ ft^2$

$d_{MHHW} = 31.2\ ft$

$d_{MLLW} = 19.4\ ft$

$V_{4MHHW} = (A_4)\ (d_{MHHW}) = 5.248 \times 10^7\ ft^3$

$V_{4MLLW} = (A_4)\ (d_{MLLW}) = 3.263 \times 10^7\ ft^3$

Section 5 - Intertidal Area North of Section 4

$A_5 = 0.712 \times 10^6\ ft^2$

$d_{MHHW} = 11.8\ ft$ Depth is assumed to decrease linearly from 11.8' to 0'

$d_{MLLW} = 0\ ft$ Not average depths

$V_{5MHHW} = 1/2\ (A_5)\ (11.8\ ft) = 4.201 \times 10^6\ ft^3$

$V_{5MLLW} = 0\ ft^3$

Section 6 - Lincoln Avenue to Upper Turning Basin

$A_6 = 2.576 \times 10^6\ ft^2$

$d_{MHHW} = 36.4\ ft$

$d_{MLLW} = 24.6\ ft$

$V_{6MHHW} = (A_6)\ (d_{MHHW}) = 9.377 \times 10^7\ ft^3$

$V_{6MLLW} = (A_6)\ (d_{MLLW}) = 6.337 \times 10^7\ ft^3$

Section 7 - Upper Turning Basin

$A_7 = 1.803 \times 10^6\ ft^2$

$d_{MHHW} = 38.9\ ft$

$d_{MLLW} = 27.1\ ft$

$V_{7MHHW} = (A_7)\ (d_{MHHW}) = 7.014 \times 10^7\ ft^3$

$V_{7MLLW} = (A_7)\ (d_{MLLW}) = 4.886 \times 10^7\ ft^3$

$V_T = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7$

$V_{TMHHW} = 31.16 \times 10^7\ ft^3$

$V_{TMLLW} = 18.451 \times 10^7\ ft^3$

$$t = \frac{(x)\ (V_L)}{(V_H - V_L)}$$

Where: x = fraction of original basin water to be replaced

V_L = basin volume at MLLW

V_H = basin volume at MHHW

The second method assumed that there was complete mixing of incoming and basin water on each flood tide; that the following ebb tide removed this mixture, and that again there was no refluxing. As with the first method, these assumptions are probably unrealistic with respect to the six waterways for the reasons already discussed. There will most likely not be 100 percent mixing in all of the six waterways. The flushing rate in tidal days (t) using this second method is given as follows:

$$t = \frac{\ln Z}{\ln (V_L/V_H)}$$

Where: Z = fraction of original basin water remaining in the basin after time t

V_L = basin volume at MLLW

V_H = basin volume at MHHW

The use of the two methods with the diurnal tide range will produce results which are conservative with respect to the use of a semidiurnal tide range. However, the results may or may not be conservative with respect to the actual flushing rates depending upon the characteristics of an individual waterway, the influences of winds, freshwater inputs, and the complicated circulation characteristics of the waterways.

3.3 RESULTS

The results of the application of the two methods on six waterways at the head of Commencement Bay are presented in Tables 9 and 10 and in summary form in Table 11. It can be seen that the second method, that which assumes 100 percent mixing, gives significantly more conservative results than those of the first method, at times by more than a factor of 10.

TABLE 9

FLUSHING RATES IN DAYS ASSUMING NO MIXING

	V_L	V_H	$V_H - V_L$	$\frac{V_L}{V_H - V_L}$	$t = [(x)(V_L)]/[V_H-V_L]$ for x = 0.5	0.75	0.9	1.0
City Waterway	8.41209 $\times 10^7$ ft^3	13.38107 $\times 10^7$ ft^3	4.96898 $\times 10^7$ ft^3	1.693	0.847 (0.88)	1.27 (1.31)	1.524 (1.58)	1.693[a] (1.75)[b]
Middle Waterway	5.4689 $\times 10^6$ ft^3	16.8618 $\times 10^6$ ft^3	1.13929 $\times 10^7$ ft^3	0.480	0.24 (0.25)	0.36 (0.37)	0.432 (0.45)	0.48 [a] (0.50)[b]
Milwaukee Waterway	3.93984 $\times 10^7$ ft^3	5.2992 $\times 10^7$ ft^3	1.35936 $\times 10^7$ ft^3	2.898	1.449 (1.50)	2.174 (2.25)	2.608 (2.70)	2.898[a] (3.00)[b]
Sitcum Waterway	0.760038 $\times 10^8$ ft^3	1.02459 $\times 10^8$ ft^3	2.64552 $\times 10^7$ ft^3	2.873	1.437 (1.49)	2.155 (2.23)	2.586 (2.68)	2.873[a] (2.97)[b]
Blair Waterway	38.19121 $\times 10^7$ ft^3	52.67339 $\times 10^7$ ft^3	14.48218 $\times 10^7$ ft^3	2.637	1.319 (1.37)	1.978 (2.05)	2.373 (2.46)	2.637[a] (2.73)[b]
Hylebos Waterway	18.45127 $\times 10^7$ ft^3	31.16077 $\times 10^7$ ft^3	12.7095 $\times 10^7$ ft^3	1.452	0.726 (0.75)	1.089 (1.13)	1.307 (1.35)	1.452[a] (1.50)[b]

(a) Tidal days
(b) Calendar days

TABLE 10

FLUSHING RATES IN DAYS ASSUMING 100 PERCENT MIXING

	V_L	V_H	$\ln (V_L/V_H)$	$t = \ln Z/\ln(V_L/V_H)$ for Z = 0.5	0.25	0.1	0.01
City Waterway	8.41209 x 10^7 ft^3	13.38107 x 10^7 ft^3	-0.464	1.494 (1.55)	2.988 (3.09)	4.962 (5.14)	9.925 (a) (10.27) (b)
Middle Waterway	5.4689 x 10^6 ft^3	16.8618 x 10^6 ft^3	-1.126	0.616 (0.64)	1.231 (1.27)	2.045 (2.12)	4.090 (a) (4.23) (b)
Milwaukee Waterway	3.93984 x 10^7 ft^3	5.2992 x 10^7 ft^3	-0.296	2.342 (2.42)	4.683 (4.85)	7.780 (8.05)	15.558 (a) (16.10) (b)
Sitcum Waterway	0.760038 x 10^8 ft^3	1.02459 x 10^8 ft^3	-0.299	2.318 (2.40)	4.636 (4.80)	7.701 (7.97)	15.402 (a) (15.94) (b)
Blair Waterway	38.19121 x 10^7 ft^3	52.67339 x 10^7 ft^3	-0.322	2.153 (2.23)	4.305 (4.46)	7.151 (7.40)	14.302 (a) (14.80) (b)
Hylebos Waterway	18.45127 x 10^7 ft^3	31.16077 x 10^7 ft^3	-0.524	1.323 (1.37)	2.646 (2.74)	4.394 (4.55)	8.788 (a) (9.10) (b)

(a) Tidal cycles
(b) Days (tidal cycles x 1.035)

TABLE 11

FLUSHING RATES (IN 24-HOUR DAYS)

	City Waterway	Middle Waterway	Milwaukee Waterway	Sitcum Waterway (days)	Blair Waterway	Hylebos Waterway
1. Diurnal Flushing - No mixing						
Replacement (percent)						
50 %	0.88	0.25	1.50	1.49	1.37	0.75
75 %	1.31	0.37	2.25	2.23	2.05	1.13
90 %	1.58	0.45	2.70	2.68	2.46	1.35
100 %	1.75	0.50	3.00	2.97	2.73	1.50
2. Diurnal Flushing - 100 percent mixing						
Replacement (percent)						
50 %	1.55	0.64	2.42	2.40	2.23	1.37
75 %	3.09	1.27	4.85	4.80	4.46	2.74
90 %	5.14	2.12	8.05	7.97	7.40	4.55
99 %	10.27	4.23	16.10	15.94	14.80	9.10

Calculations were also made for semi-diurnal tidal flushing, using the difference between mean high water (MHW) and mean low water (MLW) of 8.1 feet and a tidal period of 12.42 hours, using the same methods as employed in the diurnal calculations. For this average tide (8.1 feet) the flushing rates were approximately 30 percent faster. For example, in Milwaukee Waterway the diurnal flushing rate for t = 0.5 is 1.50 days (Table 9) and the semi-diurnal calculation indicates a rate of 1.15 days for the calculations which assumed no-mixing of incoming and outgoing water.

Semi-diurnal rates will vary considerably because of the mixed tide in Puget Sound. The rates will be much faster for extreme tides (range of 16 feet) as compared to the small tide range (which may be less than 3 feet). These fluxuations are more realistically averaged when the diurnal computations are used. Because of the semi-diurnal component of the tides, the flushing rates will be faster than those presented in the diurnal calculations of Table 11.

As discussed previously, the results presented in Table 11 are modified by the fact that: (1) the actual mixing between incoming and basin waters is probably somewhere between 0 and 100 percent; (2) in the longer waterways, the tidal excursion distances are great enough to ensure some refluxing of exiting water; and (3) the circulation patterns are significantly more complex than a simple assumption of one-dimensional ebb and flood of tidal water. The techniques which were utilized, although only approximate, will provide useful results for which comparisons between the waterways can be made based upon factors not considered in this analysis.

4.0 FIELD STUDIES - COMMENCEMENT BAY

4.1 INTRODUCTION

Past studies of currents in Commencement Bay include Brown and Caldwell (1957), Weitkamp and Campbell (1978) and Northwest Consultant Oceanographers (in Parametrix 1979a, b). The studies by Brown and Caldwell included several days of drogue work with drogues launched along the south shoreline and in the center of the bay. Drogue runs were as long as 8 to 10 hours and reversals of flow with tidal changes were evident. Drogues were set at 3 m, 30 m, and 61 m. Preliminary tide model studies were conducted by Brown and Caldwell using the University of Washington's hydraulic tide model of Puget Sound. Those tide model studies indicated a counterclockwise flow within the bay. The deeper drogues of Brown and Caldwell generally supported this counterclockwise flow at depth. The drogues at 10 feet generally paralleled the shore along the south shoreline.

The studies by Weitkamp and Campbell were conducted for the St. Regis Pulp Mill to evaluate dispersal from their outfall near the Puyallup River mouth. Drogues were set at 1 m and spread rapidly out into the middle of Commencement Bay.

The studies by Northwest Consultant Oceanographers (NCO) were performed in support of the City of Tacoma's application to the EPA for a 301(h) waiver of secondary treatment requirements. A proposed outfall site 0.4 nautical mile northwest of the mouth of the Puyallup River was evaluated by use of current meters and launches of drogues at 1 m, 5 m, 10 m, 20 m, and 35 m. These studies indicated considerable shear existed from the plume of the Puyallup River. Some current meter observations were made in the upper foot and indicated twice the speed as that observed at 1 m. NCO evaluated currents in a similar fashion for the Ruston sewer outfall site. The studies at this site indicated that the currents flowed to the northwest on both falling and rising tides. NCO further conducted more detailed hydraulic model studies than the earlier Brown and Caldwell work and evaluated dispersion from these sites.

During the summer of 1980, NOAA deployed moored current meters within Commencement Bay as part of their Marine Ecosystem Analysis (MESA) program. The results of their studies are not available at this time.

NCO studied currents in Commencement Bay in September 1980 and February 1981. The objective was to assess the circulation patterns nearshore for "average" tidal conditions and for periods of low and high river flows. The sections below detail the methods, results, and conclusions of this latter study.

4.2 METHODS

The bay was divided into four sections for the purposes of this study: (1) Ruston shoreline, (2) Old Tacoma shoreline, (3) the open waters of the bay located off the waterways, and (4) the north shore (see Figure 33). One chaser boat worked one section a day. Drogues were launched at two or three sites within each area for the rising and falling tidal period. Relaunches of drogues provided insights into the current patterns at the time of high or low water stand.

During the summer study (September 9-10, 1980), the river flow averaged 1,750 cfs (see Table 1). Drogues were launched at 0.1 m, 0.5 m, 1 m, 5 m, 10 m, and 20 m from two small boats. During the winter study (February 9-12, 1981), the river flow varied from 1,590 to 1,960 cfs during the first 3 days. Because of heavy rain and snowfall during these days, the river flow increased to 6,290 cfs on the February 12, 1981. During the winter study, drogues were launched at the same depths as the summer study and also at 40 m from the Corps of Engineers research vessel SEIGLEY. The use of the SEIGLEY proved necessary because weather conditions varied from calm to high winds with sunshine, snow, fog, and rain.

Drogue positions were determined from horizontal angles between known landmarks, measured by use of sextants. These positions were converted to geographic coordinates using an IBM 1130 computer. Trajectories were plotted and speed and direction values between fixes computed and tabulated. The actual plots and tabulations are available at the Corps of Engineers, Seattle District. For this report, the current patterns defined by the drogue movements are presented for the rising and falling tides and the data covering several days observations were integrated.

4.3 RESULTS

4.3.1 Summer Study (September 9-10, 1980)

Figures 35 through 37 present the circulation patterns observed for a falling tide of 9 feet, a low tide stand, and a rising tide of 10 feet. These figures present current patterns and average speeds based on numerous drogue trajectories.

On the falling tide (Figure 35), current speeds decrease with depth. At 0.1 m, currents of 0.75 to 0.8 kt were measured near the Hylebos Waterway and the Puyallup River mouth. The flow in the upper meter was generally to the northwest in all parts of the bay. At 5 m, a counter-clockwise flow was evident along the waterways and Old Tacoma shoreline. At 10 m, the flow along the Old Tacoma shoreline was to the southeast, and flows along the waterways were variable. At 20 m, there was evidence of a counterclockwise motion in the bay with the strongest currents along the Old Tacoma shoreline.

At low tide (see Figure 36), the currents were generally weaker and southeasterly flow was observed at all depths although much variability in direction also occurred. In the south pocket of the bay near City Waterway, the currents were weak and variable.

On the rising tide (see Figure 37), clockwise circulation was evident in the upper meter, a convergence of flow was evident off Old Tacoma heading out into the middle of the bay, and northwesterly flow was evident along the Ruston shoreline. The flow at 5 m was highly variable and at 10 and 20 m a counterclockwise flow was evident.

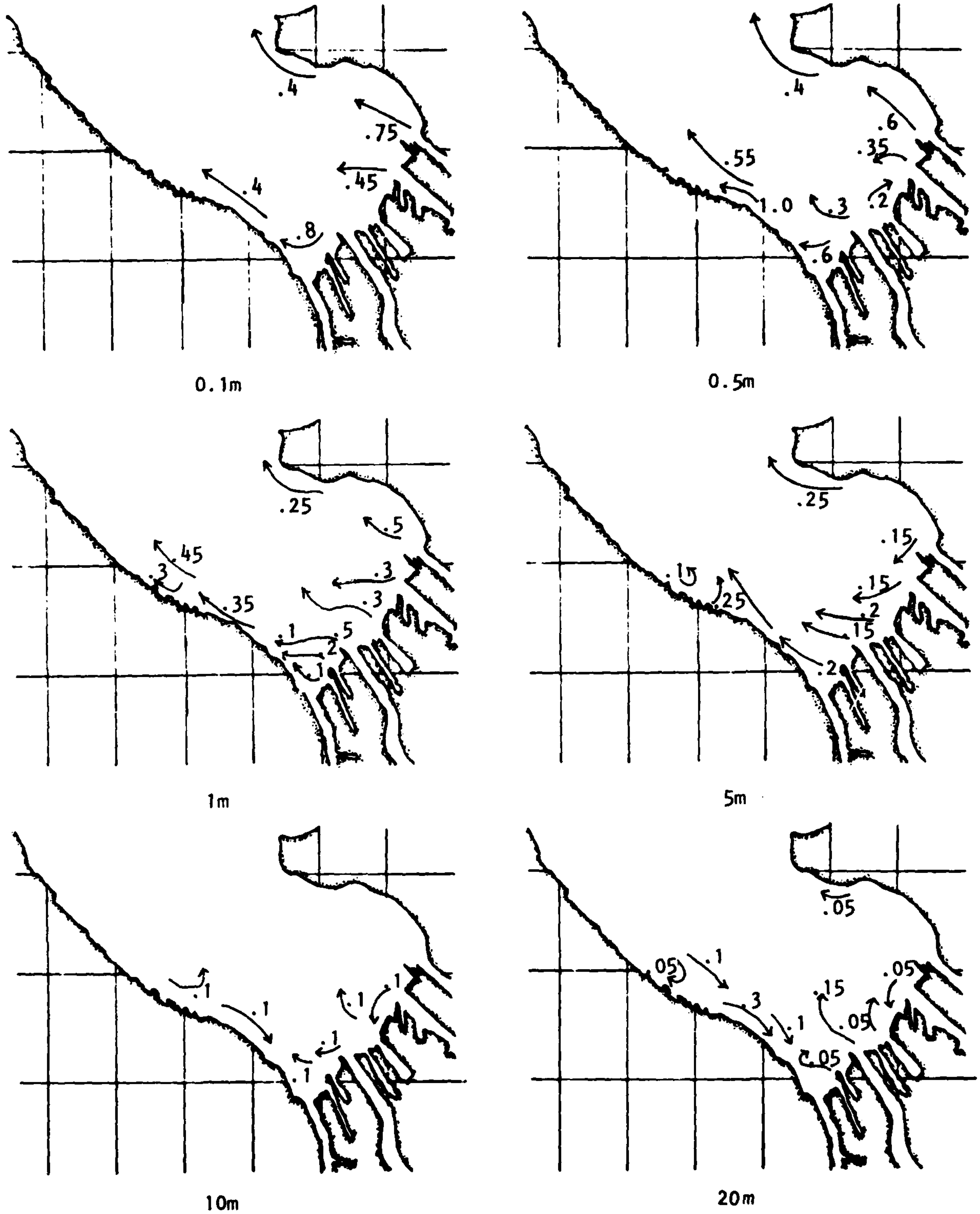


Figure 35

COMMENCEMENT BAY CURRENTS DURING A FALLING TIDE ON 9-10 SEPTEMBER 1980 (Speed In Knots)

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COMMENCEMENT BAY STUDY. VOLUME VI. PHYSICAL OCEANOGRAPHY.(U)
DEC 81 L C LOEHR, E B COLLIAS, R H SULLIVAN DACW67-80-C-0101
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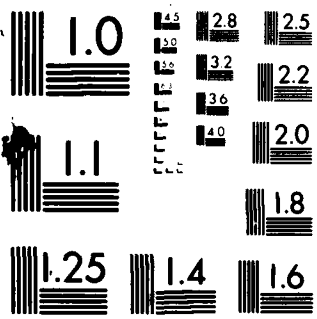

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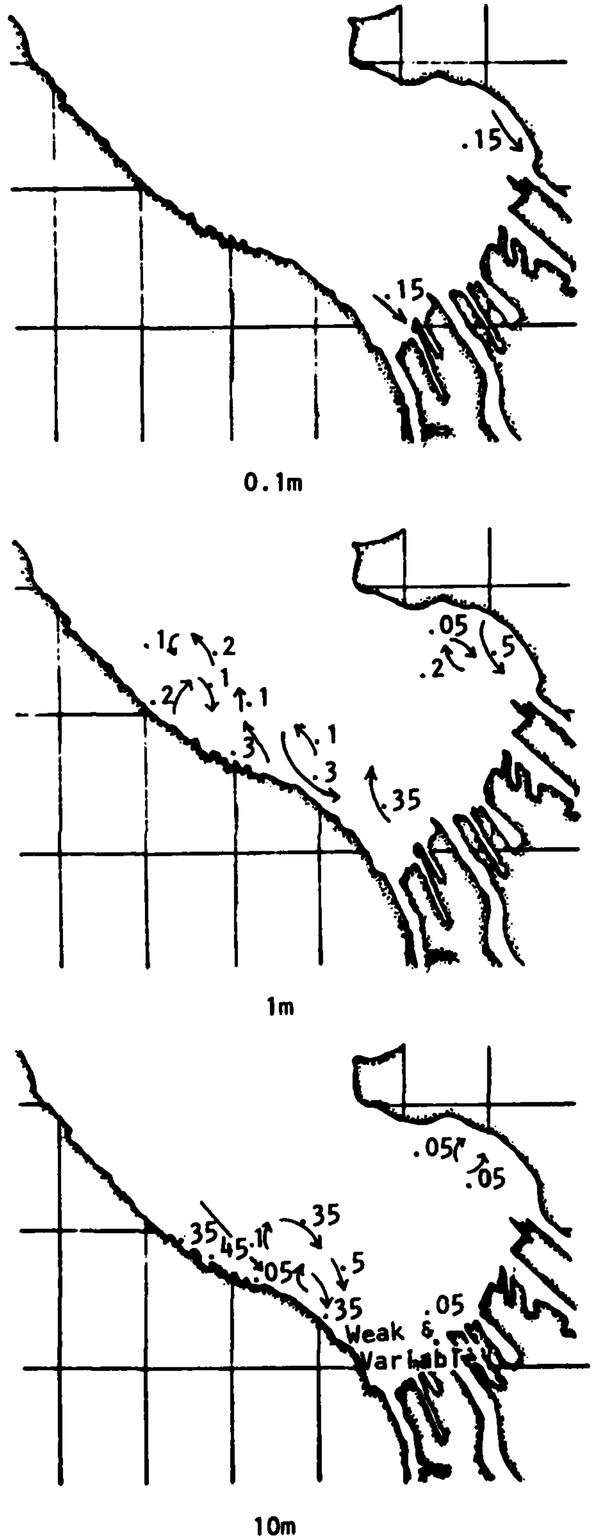

FIGURE 36
COMMENCEMENT BAY CURRENTS
AT LOW TIDE ON 9-10 SEPTEMBER 1980
(Speed in Knots)

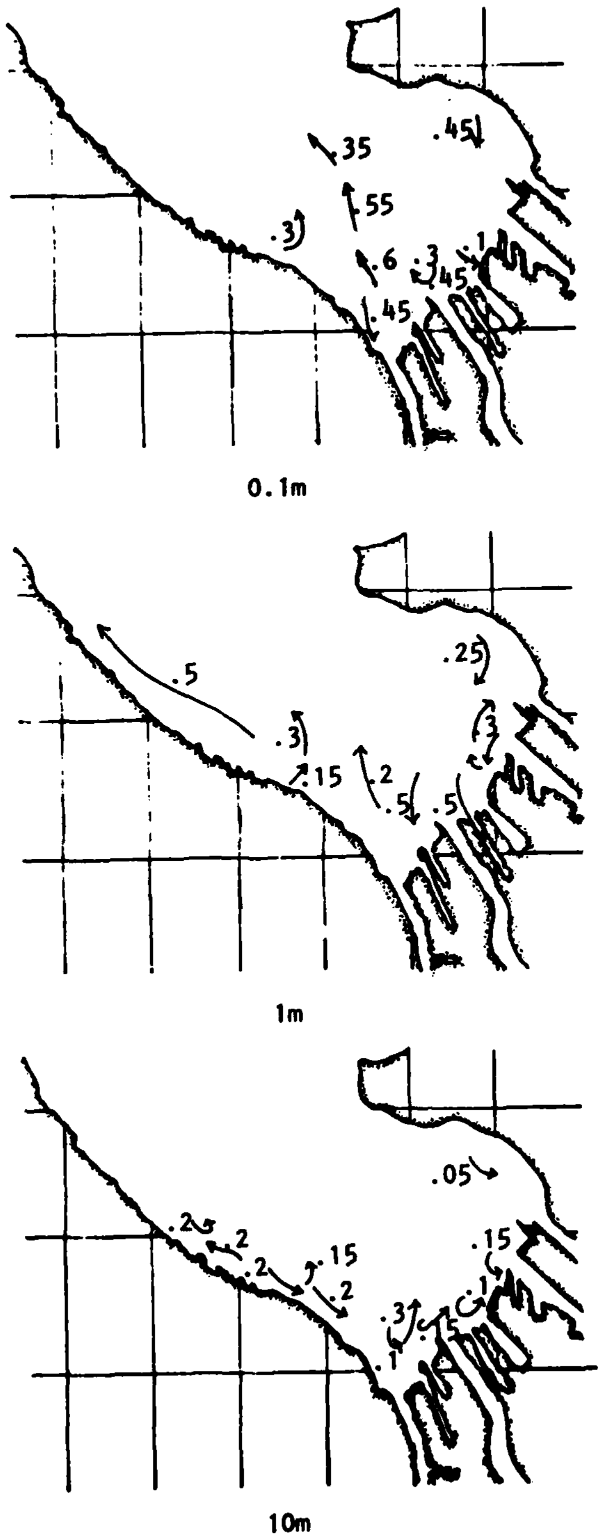

FIGURE 37
COMMENCEMENT BAY CURRENTS
DURING A RISING TIDE ON 9-10 SEPTEMBER 1980
(Speed in Knots)

4.3.2 Winter Study (February 9-12, 1981)

Figures 38 and 39 present the current patterns observed for rising and falling tide conditions observed during the winter study. The falling tide ranges increased from 10 to 11 feet while the rising tide ranges remained at 9 feet during the 4-day study period.

Water movement on the rising tide exhibited a clear clockwise rotation from the surface to 20 m but not at 40 m where the current was weak and variable (Figure 38). Off the Old Tacoma shoreline, surface currents were to the north. These currents became more westerly with increasing depth until at 5 m the currents paralleled the shore.

On the falling tide (see Figure 39), waters at all depths tended to flow toward the northwest with speeds that decreased with depth. The tendency for clockwise circulation that was observed from 0 m to 20 m on the rising tide was not apparent during the falling tide.

Along the Ruston and Old Tacoma shorelines, the water motion from 0 m to 10 m flowed parallel to the shore while the water at 0.1 m and 1 m had an offshore (northward) component. From 10 m to 40 m, the waters tended to move onshore.

Off the mouth of the Puyallup River and southward along the waterways, there was a relatively strong flow (0.5 kt at 0.1 m and decreasing with depth) to the northwest. Along the northern entrances to the waterways, the current direction was [illegible] variable. Water at 0.1 m and 1 m flowed to the northeast, while water [illegible] 5 m and 10 m flowed to the southwest. At 20 m and 40 m, the current was weak (0.05 kt) and variable with a slight tendency to flow toward the northeast.

In the northern part of Commencement Bay, the water at 0.1 m to 10 m flowed offshore and to the northwest past Browns Point. The waters at 20 m and 40 m demonstrated a weak (0.05 kt) toward-shore flow yet still flowed to the northwest past Browns Point.

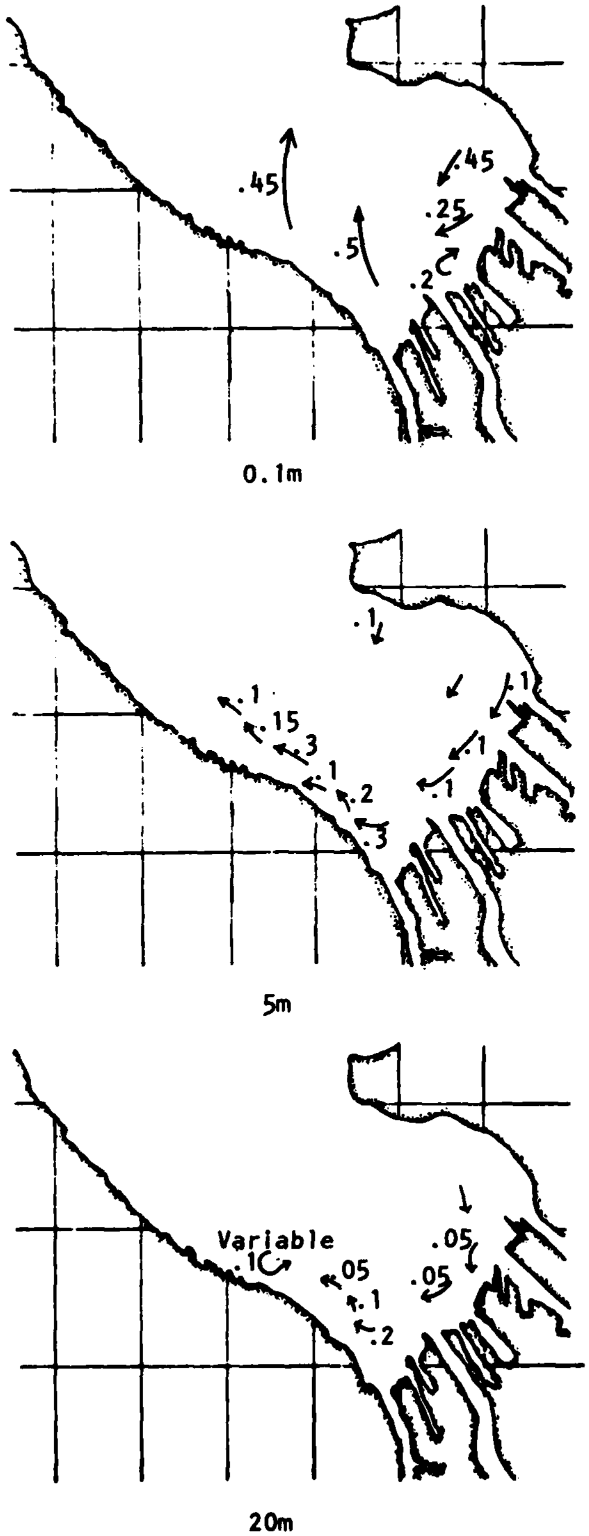

FIGURE 38
COMMENCEMENT BAY CURRENTS
DURING A RISING TIDE ON 9-12 FEBRUARY 1981
(Speed In Knots)

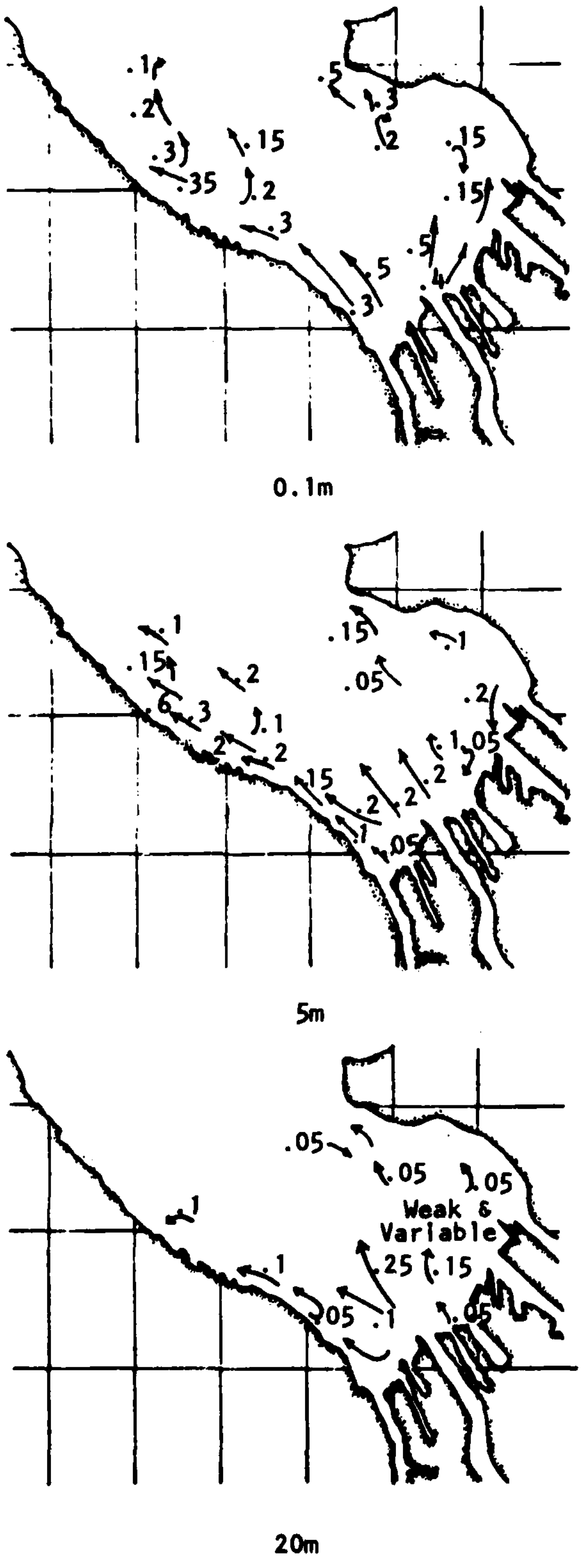

FIGURE 39
COMMENCEMENT BAY CURRENTS
DURING A FALLING TIDE ON 9–12 FEBRUARY 1981
(Speed in Knots)

5.0 WAVE ANALYSIS

5.1 INTRODUCTION

The purpose of this section is to evaluate wind-generated wave conditions along the southern shore of Commencement Bay, extending from Ruston on the west to the entrance of City Waterway on the east. Three locations were selected for the analysis along this 4-mile length of shoreline. The first station was located at 47° 18.1' N, 122° 30.0' W just offshore of the ASARCO smelter. The middle station was located at 47° 17.0'N, 122° 28.4'W, and the third station at 47°16.1'N, 122°26.6'W just north of the Port of Tacoma grain elevator. The analysis utilized historical wind data and the effective fetch to produce the wave roses illustrated in Figure 40.

5.2 METHOD

The analysis of wave conditions at the three stations incorporated three different types of calculations. First, the historical wind data were analyzed to evaluate the frequency of occurrence of winds of selected magnitudes from selected directions. Due to the limited scope of this analysis, the primary wind data set used was from a 2-year record obtained at Point Robinson on the northeast tip of Maury Island. A summary of these data is presented in Table 12. These winds are most representative as they reflect local winds near the water surface unlike the stations at Sea-Tac Airport or McChord AFB which are over 300 feet above sea level. The Sea-Tac weather data were compared to the Point Robinson data and the extreme winds obtained. Wind roses from Harris and Rattray (1954) and Phillips (1968) were used as a check to ensure that the general patterns in Commencement Bay were correctly represented.

The wind data were reduced to compass points in order to simplify calculations. The assumption was made that one-half of the frequency of occurrence of winds from the unused compass points on either side of the primary points contributed to the frequency at any particular primary point. Thus, for example, a wind from the north is made up of the data

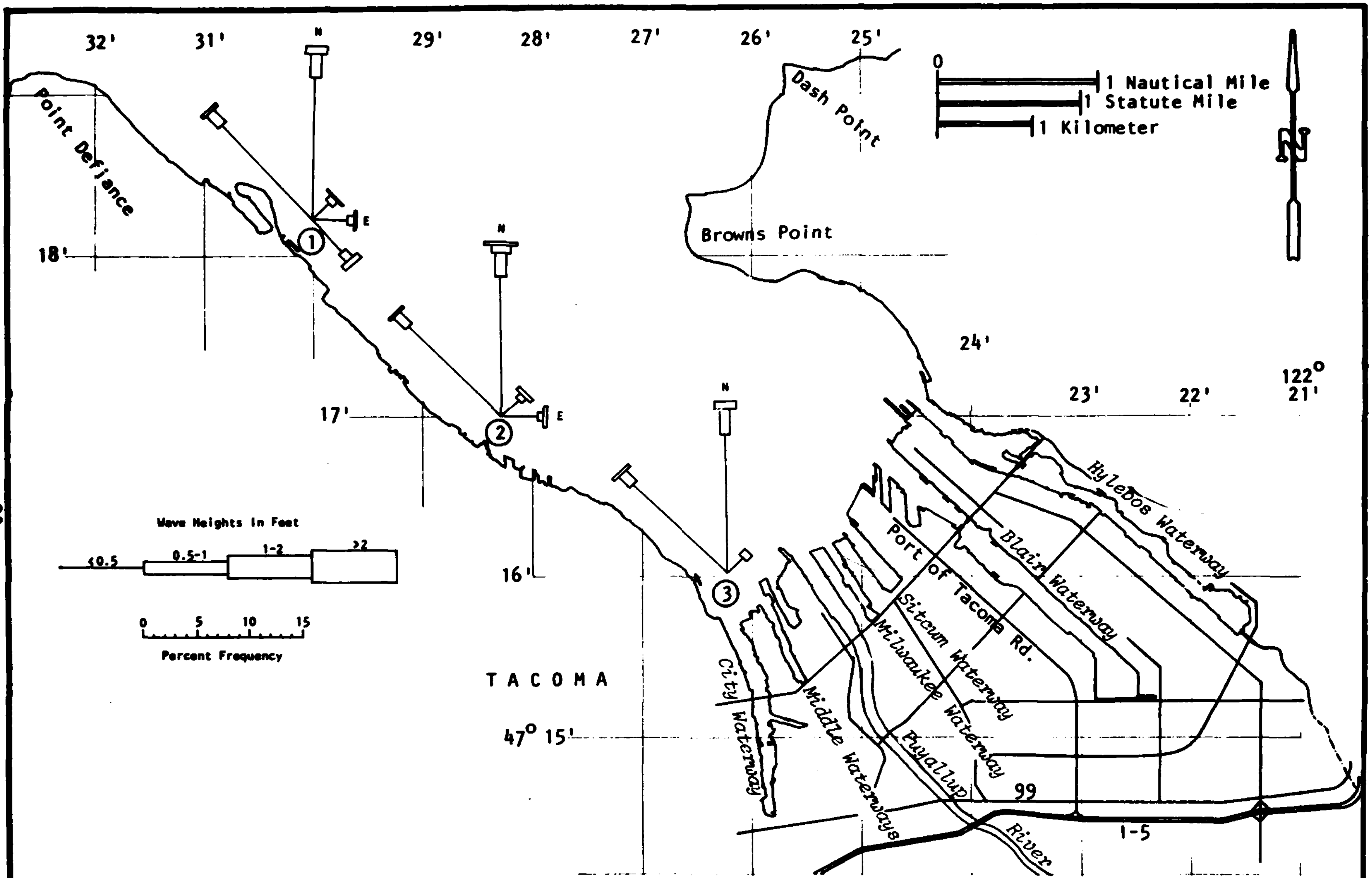

FIGURE 40
ANNUAL WAVE ROSES FOR RUSTON AND OLD TACOMA SHORE, COMMENCEMENT BAY

TABLE 12

PERCENT FREQUENCY OF OCCURRENCE OF WINDS AT POINT ROBINSON STATION
FOR THE PERIOD JANUARY 22, 1970 TO DECEMBER 19, 1971

		Wind Speed (mph)								
Direction		1.5-3	4-7	8-11	12-18	19-24	25-31	32-38	39-44	Over 44	Total
N		1.45	5.70	1.35	0.45	0.10					9.05
NNE		0.45	1.00	0.35	0.15						1.95
NE		0.35	0.50	0.15	0.05						1.05
ENE		0.50	0.55	0.10	0.05						1.20
E		1.05	1.00	0.10	0.10						2.25
ESE		0.90	0.90	0.20							2.00
SE		0.80	0.90	0.30	0.10						2.10
SSE		1.25	1.90	1.00	0.55	0.15					4.85
S		3.55	8.25	5.20	6.35	1.50	0.30				25.15
SSW		3.15	6.10	2.70	2.05	0.55					14.55
SW		1.85	1.00	0.20	0.05						3.10
WSW		1.55	0.25								1.80
W		2.50	0.30								2.80
WNW		1.45	0.35								1.80
NW		2.15	3.80	0.85							6.80
NNW		1.95	8.80	1.60	0.20						12.55
CALM	7.00										7.00
TOTAL	7.00	24.90	41.30	14.10	10.10						100.00

Source: Unpublished data, University of Washington Department of Oceanography.

from the north, one-half of the data from the north-northeast, and one-half of the data from the north-northwest, while a northeast wind is comprised of northeast data, the other half of the north-northeast data, and one-half of the east-northeast data. The results are presented in Table 13. No analysis was conducted on wind duration because the fetch lengths were short enough to ensure that wave generation was limited by the fetch and not by the duration of the wind.

Second, an analysis of the fetch lengths for each wind direction at each of the three selected stations was conducted. Because of the confined nature of Commencement Bay and the irregular nature of the shoreline, it became necessary to account for these factors through the calculation of an effective fetch (F_E) by the method discussed in the Shore Protection Manual.* In order to reduce the amount of computation involved, those directions at each station where the wind would not generate waves of any consequence were eliminated.

Following the application of this method, those directions which had an effective fetch of less than 1 nautical mile were also eliminated again due to the lack of size of waves generated over a fetch of this length for the wind speeds considered. The data used for the effective fetch calculations are presented in Table 14. A summary of the directions finally selected for the wave height analysis and the effective fetches associated with these directions is presented in Table 15.

Third, using the Sverdrup-Munk-Bretschneider (SMB) method as described in the Shore Protection Manual**, wave heights (H_s) and significant periods (T_s) for the directions and fetches selected at each station were computed. The assumptions made were: (1) for each range of wind speeds, the speed at the top of the range was used as input; (2) because of the relatively short fetch lengths, wave growth was fetch-limited; and (3) a particular wind, and hence wave growth, starts from a calm condition. This last assumption precludes the determination of the growth of larger

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*Volume I, pages 3-30 through 3-33, U.S. Army Corps of Engineers 1973.

**Volume I, pages 3-33 through 3-34, U.S. Army Corps of Engineers 1973.

TABLE 13

REDUCTION OF 16-POINT COMPASS TO 8-POINT COMPASS

	Wind Speed (mph)						
Direction	1.5-3	4-7	8-11	12-18	19-24	25-31	Total
N Wind							
N	1.450	5.700	1.350	0.450	0.100		
1/2 NNE	0.225	0.500	0.175	0.075	0.000		
1/2 NNW	0.975	4.400	0.800	0.100	0.000		
Total	2.650	10.600	2.325	0.625	0.100		16.300
NE Wind							
NE	0.350	0.500	0.150	0.005			
1/2 NNE	0.225	0.500	0.175	0.075			
1/2 ENE	0.250	0.275	0.050	0.025			
Total	0.825	1.275	0.375	0.150			2.625
E Wind							
E	1.050	1.000	0.100	0.100			
1/2 ENE	0.250	0.275	0.050	0.025			
1/2 ESE	0.450	0.450	0.100	0.000			
Total	1.750	1.725	0.250	0.125			3.850
SE Wind							
SE	0.800	0.900	0.300	0.100	0.000		
1/2 ESE	0.450	0.450	0.100	0.000	0.000		
1/2 SSE	0.625	0.950	0.500	0.275	0.075		
Total	1.875	2.300	0.900	0.375	0.075		5.525
S Wind							
S	3.550	8.250	5.200	6.350	1.500	0.300	
1/2 SSE	0.625	0.950	0.500	0.275	0.075	0.000	
1/2 SSW	1.575	3.050	1.350	1.025	0.275	0.000	
Total	5.750	12.250	7.050	7.650	1.850	0.300	34.850
SW Wind							
SW	1.850	1.000	0.200	0.050	0.000		
1/2 SSW	1.575	3.050	1.350	1.025	0.275		
1/2 WSW	0.775	0.125	0.000	0.000	0.000		
Total	4.200	4.175	1.550	1.075	0.275		11.275

TABLE 13

Direction	Wind Speed (mph) 1.5-3	4-7	8-11	12-18	19-24	25-31	Total
W Wind							
W	2.500	0.300					
1/2 WSW	0.775	0.125					
1/2 WNW	0.725	0.175					
Total	4.000	0.600					4.600
NW Wind							
NW	2.150	3.800	0.850	0.000			
1/2 WNW	0.725	0.175	0.000	0.000			
1/2 NNW	0.975	4.400	0.800	0.100			
Total	3.850	8.375	1.650	0.100			13.975
Calm							7.000
Total							100.000

TABLE 14

EFFECTIVE FETCH LENGTHS FOR WAVE STATIONS IN COMMENCEMENT BAY
STATION 1

Sheet 1 of 3

		Effective Fetch (F_E)[a] (nautical miles)											
		N		NE		E		SE		S		NW	
α	$\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$
42	0.743	2.5	1.8575	1.2	0.8916	6.7	4.9781	1.9	1.4117	1.2	0.8916	0.0	0.0000
36	0.809	2.9	2.3461	1.4	1.1326	7.0	5.6630	3.0	2.4270	1.1	0.8899	0.0	0.0000
30	0.866	3.5	3.0310	4.5	3.8970	7.0	6.0620	3.3	2.8578	0.6	0.5196	0.0	0.0000
24	0.914	3.9	3.5646	2.7	2.4678	7.1	6.4894	3.4	3.1076	0.4	0.3656	0.0	0.0000
18	0.951	1.9	1.8069	2.7	2.5677	2.9	2.7579	3.6	3.4236	0.4	0.3804	0.0	0.0000
12	0.978	1.9	1.8582	2.8	2.7384	2.7	2.6406	3.4	3.3252	0.0	0.0000	0.0	0.0000
6	0.995	1.8	1.7910	5.7	5.6715	2.3	2.2885	3.5	3.4825	0.0	0.0000	0.0	0.0000
0	1.000	1.7	1.7000	9.1	9.1000	2.3	2.3000	2.1	2.1000	0.0	0.0000	3.4	3.4000
6	0.995	1.7	1.6915	8.7	8.6565	3.3	3.2835	1.4	1.3930	0.0	0.0000	3.5	3.4825
12	0.978	1.8	1.7604	8.1	7.9218	3.7	3.6186	0.8	0.7824	0.0	0.0000	3.7	3.6186
18	0.951	5.0	4.7550	7.5	7.1325	3.5	3.3285	0.0	0.0000	0.0	0.0000	4.0	3.8040
24	0.914	2.6	2.3764	5.1	4.6614	3.3	3.0162	0.0	0.0000	0.0	0.0000	1.9	1.7366
30	0.866	2.5	2.1650	2.5	2.1650	3.1	2.6846	0.0	0.0000	0.0	0.0000	1.6	1.3856
36	0.809	2.4	1.9416	2.2	1.7798	2.8	2.2652	0.0	0.0000	0.0	0.0000	1.5	1.2135
42	0.743	4.7	3.4921	1.6	1.1888	2.6	1.9318	0.0	0.0000	0.0	0.0000	1.3	0.9659
$\Sigma\cos\alpha =$ 13.512		$\Sigma\chi_i\cos\alpha =$ 36.1373		$\Sigma\chi_i\cos\alpha =$ 61.9724		$\Sigma\chi_i\cos\alpha =$ 53.3016		$\Sigma\chi_i\cos\alpha =$ 24.3108		$\Sigma\chi_i\cos\alpha =$ 3.0471		$\Sigma\chi_i\cos\alpha =$ 19.6067	
		$F_E = \frac{36.1373}{13.512}$		$F_E = \frac{61.9724}{13.512}$		$F_E = \frac{53.3016}{13.512}$		$F_E = \frac{24.3108}{13.512}$		$F_E = \frac{3.0471}{13.512}$		$F_E = \frac{19.6067}{13.512}$	
		$F_E =$ 2.67		$F_E =$ 4.59		$F_E =$ 3.94		$F_E =$ 1.79		$F_E =$ 0.23		$F_E =$ 1.45	
		$F_E =$ 2.7 nm		$F_E =$ 4.6 nm		$F_E =$ 3.9 nm		$F_E =$ 1.8 nm		$F_E =$ 0.2 nm		$F_E =$ 1.5 nm	

(a) $F_E = \frac{\Sigma\chi_i\cos\alpha}{\Sigma\cos\alpha}$

TABLE 14

STATION 2

		Effective Fetch (F_E)[a] (nautical miles)											
		N		NE		E		SE		S		NW	
α	$\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$	X_i	$X_i\cos\alpha$
42	0.743	3.7	2.7491	2.7	2.0061	1.3	0.9659	1.8	1.3374	0.0	0.0000	0.0	0.0000
36	0.809	4.2	3.3978	2.9	2.3461	1.3	1.0517	1.9	1.5371	0.0	0.0000	0.0	0.0000
30	0.866	4.9	4.2434	3.4	2.9444	1.5	1.2990	2.0	1.7320	0.0	0.0000	0.0	0.0000
24	0.914	3.0	2.7420	4.9	4.4786	1.8	1.6452	2.0	1.8280	0.0	0.0000	0.0	0.0000
18	0.951	2.8	2.5528	5.9	5.6109	2.3	2.1873	1.9	1.8069	0.0	0.0000	0.5	0.4755
12	0.978	2.9	2.8362	6.9	6.7482	2.5	1.4450	2.0	1.9560	0.0	0.0000	0.6	0.5868
6	0.995	4.4	4.3780	9.0	8.9550	2.7	1.2865	0.6	0.5970	0.0	0.0000	1.2	1.1940
0	1.000	6.0	6.0000	1.8	1.8000	2.6	2.6000	0.5	0.5000	0.0	0.0000	1.7	1.7000
6	0.995	3.6	3.5820	1.6	1.5920	2.5	2.4875	0.0	0.0000	0.0	0.0000	5.0	4.9750
12	0.978	3.5	3.4230	1.7	1.6626	2.3	2.2494	0.0	0.0000	0.3	0.2934	5.3	5.1834
18	0.951	4.8	4.5648	1.8	1.7118	2.3	2.1873	0.0	0.0000	0.3	0.2853	3.2	3.0432
24	0.914	5.3	4.8442	2.1	1.9194	1.8	1.6452	0.0	0.0000	0.4	0.3656	2.7	2.4678
30	0.866	5.8	5.0228	2.2	1.9052	1.7	1.4722	0.0	0.0000	0.4	0.3464	2.5	2.1650
36	0.809	7.5	6.0675	2.2	1.7798	0.6	0.4854	0.0	0.0000	0.7	0.5663	2.9	2.3461
42	0.743	6.7	4.9781	2.0	1.4860	0.5	0.3715	0.0	0.0000	0.9	0.6687	4.1	3.0463
$\Sigma\cos\alpha =$ 13.512		$\Sigma X_i\cos\alpha =$ 61.4917		$\Sigma X_i\cos\alpha =$ 46.9461		$\Sigma X_i\cos\alpha =$ 25.7791		$\Sigma X_i\cos\alpha =$ 11.2944		$\Sigma X_i\cos\alpha =$ 2.5257		$\Sigma X_i\cos\alpha =$ 27.1831	
		$F_E = \frac{61.4917}{13.512}$		$F_E = \frac{46.9461}{13.512}$		$F_E = \frac{25.7791}{13.512}$		$F_E = \frac{11.2944}{13.512}$		$F_E = \frac{2.5257}{13.512}$		$F_E = \frac{27.1831}{13.512}$	
		$F_E =$ 4.55		$F_E =$ 3.47		$F_E =$ 1.91		$F_E =$ 0.84		$F_E =$ 0.19		$F_E =$ 2.01	
		$F_E =$ 4.6 nm		$F_E =$ 3.5 nm		$F_E =$ 1.9 nm		$F_E =$ 0.8 nm		$F_E =$ 0.2 nm		$F_E =$ 2.0 nm	

TABLE 14

STATION 3

Sheet 3 of 3

α	$\cos\alpha$	N X_i	N $X_i\cos\alpha$	NE X_i	NE $X_i\cos\alpha$	E X_i	E $X_i\cos\alpha$	SE X_i	SE $X_i\cos\alpha$	S X_i	S $X_i\cos\alpha$	NW X_i	NW $X_i\cos\alpha$
		Effective Fetch (F_E)[a] (nautical miles)											
42	0.743	4.9	3.6407	1.3	0.9659	1.4	1.0402	0.4	0.2972	0.0	0.0000	0.0	0.0000
36	0.809	3.9	3.1551	1.4	1.1326	1.4	1.1326	0.4	0.3236	0.0	0.0000	0.0	0.0000
30	0.866	3.7	3.2042	1.5	1.2990	1.2	1.0392	0.4	0.3464	0.0	0.0000	0.0	0.0000
24	0.914	4.3	3.9302	1.7	1.5538	1.0	0.9140	0.4	0.3656	0.0	0.0000	0.0	0.0000
18	0.951	5.5	5.2305	1.8	1.7118	0.9	0.8559	0.5	0.4755	0.0	0.0000	0.0	0.0000
12	0.978	4.5	4.4010	1.9	1.8582	1.0	0.9780	0.5	0.4890	0.0	0.0000	0.0	0.0000
6	0.995	4.4	4.3780	1.9	1.8905	0.7	0.6965	0.5	0.4975	0.0	0.0000	3.2	3.1840
0	1.000	1.9	1.9000	1.9	1.9000	0.5	0.5000	0.5	0.5000	0.0	0.0000	6.4	6.4000
6	0.995	1.8	1.7910	1.8	1.7910	0.5	0.4975	0.4	0.3980	0.0	0.0000	6.9	6.8655
12	0.978	1.7	1.6626	1.4	1.3692	0.5	0.4890	0.7	0.6846	0.0	0.0000	4.3	4.2054
18	0.951	1.7	1.6167	1.2	1.1412	0.4	0.3804	0.8	0.7608	0.0	0.0000	4.0	3.8040
24	0.914	1.7	1.5538	0.9	0.8226	0.4	0.3656	0.0	0.0000	0.0	0.0000	4.8	4.3872
30	0.866	1.7	1.4722	0.9	0.7794	0.5	0.4330	0.0	0.0000	0.0	0.0000	5.6	4.8496
36	0.809	1.6	1.2944	0.6	0.4854	0.3	0.2427	0.0	0.0000	0.0	0.0000	3.6	2.9124
42	0.743	1.4	1.0402	0.5	0.3715	0.3	0.2229	0.0	0.0000	4.7	3.4921	3.7	2.7491
$\Sigma\cos\alpha =$ 13.512		$\Sigma X_i\cos\alpha =$ 40.2706		$\Sigma X_i\cos\alpha =$ 19.0721		$\Sigma X_i\cos\alpha =$ 9.7875		$\Sigma X_i\cos\alpha =$ 5.1382		$\Sigma X_i\cos\alpha =$ 3.4921		$\Sigma X_i\cos\alpha =$ 39.3572	
		$F_E = \frac{40.2706}{13.512}$		$F_E = \frac{19.0721}{13.512}$		$F_E = \frac{9.7875}{13.512}$		$F_E = \frac{5.1382}{13.512}$		$F_E = \frac{3.4921}{13.512}$		$F_E = \frac{39.3572}{13.512}$	
		$F_E =$ 2.98		$F_E =$ 1.41		$F_E =$ 0.72		$F_E =$ 0.38		$F_E =$ 0.26		$F_E =$ 2.91	
		$F_E =$ 3.0 nm		$F_E =$ 1.4 nm		$F_E =$ 0.7 nm		$F_E =$ 0.4 nm		$F_E =$ 0.3 nm		$F_E =$ 2.9 nm	

TABLE 15

DIRECTIONS AND EFFECTIVE FETCHES (nm) SELECTED AT EACH WAVE STATION

	N	NE	E	SE	NW
Station 1 (47°18.1'N 122°30'W)	2.7	4.6	3.9	1.8	1.5
Station 2 (47°17.1'N 122°28.45'W)	4.6	3.5	1.9		2.0
Station 3 (47°16.07'N 122°26.55'W)	3.0	1.4			2.9

waves than were calculated when the wind steadily builds in intensity over a period of time. This shortcoming was alleviated by doing an analysis of maximum waves, using historical instances of maximum winds recorded. These maximum waves are larger than those produced by an incremental build-up of wind through the range of wind speeds represented in the data base. Another assumption was that the waves generated would be deep-water waves, or that the ratio of water depth (d) to wave length (L) would be greater than 0.5 ($d/L>0.5$). This assumption is valid in that for deep-water waves:

$$L = 5.12\ T^2$$

For the conditions in Commencement Bay, waves of periods (T) greater than 4 seconds will rarely be generated. Thus, for T = 4 seconds, L = 82 feet, and "d" must be greater than 41 feet, a condition which is greatly exceeded in almost all areas of Commencement Bay. The data sheets used in the computation of H_s and T_s are presented in Table 16.

During 1970-1971 at Point Robinson, the maximum recorded wind was 38 mph from the south. The maximum wind speed at Sea-Tac Airport was 65 mph from the S in 1943 and the SW in 1962 (Phillips 1968). The wind directions of concern in this study are N, NE, E, SE, and NW because of local topography. In the period 1951-1960 at Sea-Tac Airport, the maximum recorded wind in January, April, July, or October was 46 mph from the SSW, SW, WSW (Phillips 1968). The maximum winds recorded in January, April, July, or October for the directions of concern in this study were:

N: 38 mph
NE: 38 mph
E: 31 mph
SE: 31 mph
NW: 31 mph

It seems reasonable, as a maximum case, to use 50 mph as the maximum wind speed. Again, we are fetch-limited so we assume that the duration is sufficient so that fetch-limited conditions apply. Using this wind speed precludes doing an analysis of worst-case waves by using increasing wind speeds over a period of time. A wind of 50 mph will generate waves

TABLE 16

SIGNIFICANT WAVE HEIGHTS AND PERIODS AT SELECTED STATIONS
STATION 1

Directions Considered: N, NE, E, SE, NW

Effective Fetch: N - 2.7 nm = 16,416'
NE - 4.6 nm = 27,968'
E - 3.9 nm = 23,712'
SE - 1.8 nm = 10,944'
NW - 1.5 nm = 9,120'

U mph	Fetch: Direction:	2.7 N	4.6 NE	3.9 E	1.8 SE	1.5 NW
1.5 - 3		% = 2.65 H_s : <0.5' T_s : <2s	% = 0.825 H_s : <0.5' T_s : <2s	% = 1.75 H_s : <0.5' T_s : <2s	% = 1.875 H_s : <0.5' T_s : <2s	% = 3.85 H_s : <0.5' T_s : <2s
4 - 7		% = 10.6 H_s : <0.5' T_s : <2s	% = 1.275 H_s : <0.5' T_s : <2s	% = 1.725 H_s : <0.5' T_s : <2s	% = 2.3 H_s : <0.5' T_s : <2s	% = 8.375 H_s : <0.5' T_s : <2s
8 - 11		% = 2.325 H_s : 0.5-1' T_s : <2s	% = 0.375 H_s : 0.5-1' T_s : <2s	% = 0.25 H_s : <0.5-1' T_s : <2s	% = 0.9 H_s : <0.5-1' T_s : <2s	% = 1.650 H_s : 0.5-1' T_s : <2s
12 - 18		% = 0.625 H_s : 1.3' T_s : 2.4s	% = 0.15 H_s : 1.5' T_s : 2.7s	% = 0.125 H_s : 1.45' T_s : 2.6s	% = 0.375 H_s : 1.1' T_s : 2.2s	% = 0.1 H_s : 1.0' T_s : 2.1s
19 - 24		% = 0.1 H_s : 1.7' T_s : 2.8s			% = 0.075 Hs : 1.5' Ts : 2.6s	
Total %		= 16.3	=2.625	= 3.85	=5.525	= 13.975

SMB Method: H_s and T_s - Deepwater Waves

- For all calculations the wind speed at the top of each range is used.
- Wave growth is fetch-limited.
- Wave growth, i.e., wind, starts from calm condition.

TABLE 16

STATION 2

Directions Considered: N, NE, E, NW

Effective Fetch:
N - 4.6 nm
NE - 3.5 nm
E - 1.9 nm
NW - 2.0 nm

U mph	Fetch: / Direction:	4.6 / N	3.5 / NE	1.9 / E	2.0 / NW
1.5 - 3		% = 2.65 H_s : <0.5' T_s : <2s	% = 0.825 H_s : <0.5' T_s : <2s	% = 1.75 H_s : <0.5' T_s : <2s	% = 3.85 H_s : <0.5' T_s : <2s
4 - 7		% = 10.6 H_s : <0.5' T_s : <2s	% = 1.275 H_s : <0.5' T_s : <2s	% = 1.725 H_s : <0.5' T_s : <2s	% = 8.375 H_s : <0.5' T_s : <2s
8 - 11		% = 2.325 H_s : 0.5-1' T_s : 2s	% = 0.375 H_s : 0.5-1' T_s : <2s	% = 0.25 H_s : 0.5-1' T_s : <2s	% = 1.65 H_s : 0.5-1' T_s : <2s
12 - 18		% = 0.625 H_s : 1.5' T_s : 2.7s	% = 0.15 H_s : 1.4' T_s : 2.5s	% = 0.125 H_s : 1.1' T_s : 2.2s	% = 0.1 H_s : 1.1' T_s : 2.2s
19 - 24		% = 0.1 H_s : 2.2' T_s : 3.2s			
	Total %	= 16.3	=2.625	= 3.85	=13.975

SMB Method: H_s and T_s - Deepwater Waves

- For all calculations the wind speed at the top of each range is used.
- Wave growth is fetch-limited.
- Wave growth, i.e., wind, starts from calm condition.

TABLE 16

STATION 3

Directions Considered: N, NE, NW

Effective Fetch: N - 3.0 nm
NE - 1.4 nm
NW - 2.9 nm

U mph	Fetch: / Direction:	3.0 / N	1.4 / NE	2.9 / NW
1.5 - 3		% = 2.65 H_s : <0.5' T_s : <2s	% = 0.825 H_s : <0.5' T_s : <2s	% = 3.85 H_s : <0.5' T_s : <2s
4 - 7		% = 10.6 H_s : <0.5' T_s : <2s	% = 1.275 H_s : <0.5' T_s : <2s	% = 8.375 H_s : <0.5' T_s : <2s
8 - 11		% = 2.325 H_s : 0.5-1' T_s : <2s	% = 0.375 H_s : 0.5-1' T_s : <2s	% = 1.65 H_s : 0.5-1' T_s : <2s
12 - 18		% = 0.625 H_s : 1.3' T_s : 2.4s	% = 0.15 H_s : 0.5-1' T_s : 2s	% = 0.1 H_s : 1.3' T_s : 2.4s
19 - 24		% = 0.1 H_s : 1.8' T_s : 2.8s		
Total %		= 16.3	=2.625	=13.975

SMB Method: H_s and T_s - Deepwater Waves

- For all calculations the wind speed at the top of each range is used.
- Wave growth is fetch-limited.
- Wave growth, i.e., wind, starts from calm condition.

larger than those generated by an incremental wind from minimum to maximum as defined by the 1970-1971 data at Point Robinson. Therefore, using 50-mph wind and F_E as defined, the maximum wave conditions for the three stations were computed and given in Table 17.

TABLE 17

MAXIMUM WAVE COMPUTATIONS

	Station 1		Station 2		Station 3	
N	$H_s = 4'$	$T_s = 4.2_s$	$H_s = 5'$	$T_s = 4.7_s$	$H_s = 4.3'$	$T_s = 4.5_s$
NE	$H_s = 5'$	$T_s = 4.7_s$	$H_s = 4.6'$	$T_s = 4.3_s$	$H_s = 3.1'$	$T_s = 3.5_s$
E	$H_s = 4.8'$	$T_s = 4.6_s$	$H_s = 3.5'$	$T_s = 3.7_s$		
SE	$H_s = 3.5'$	$T_s = 3.7_s$				
NW	$H_s = 3.2'$	$T_s = 3.6_s$	$H_s = 3.6'$	$T_s = 3.8_s$	$H_s = 4.2'$	$T_s = 4.4_s$

5.3 RESULTS

The results of the analysis at the three stations are depicted in tabular form in Table 18 and as wave roses in Figure 40. The wave studies indicate that the incidence of waves greater than 2 feet in height is almost negligible, while the incidence of 1-foot to 2-foot waves is approximately 1 to 1.5 percent. It should be noted that for waves less than 0.5 foot in height, the lower end of windspeeds is 3 mph; Figure 39 does not include waves less than 0.5 foot in height generated when the wind is less than 3 mph.

5.4 VISUAL OBSERVATION

On January 10, 1981, strong northwesterly winds (up to 35 kt) occurred in Commencement Bay during the afternoon and early evening. These winds produced waves of about 3 feet in height that came directly into City Waterway. The waves did not attenuate in height until east of the 11th Street Bridge and tore many boats loose from their moorage at Totem Marina. Several of the boat owners stated that such northwest winds occur about twice a year with damage occurring in City Waterway.

TABLE 18

PERCENT FREQUENCY OF OCCURRENCE OF WAVES AT SELECTED STATIONS

	N	NE	E	SE	NW	Total
Station 1						
<0.5'	13.25	2.1	3.475	4.175	12.225	35.225
0.5 - 1'	2.325	0.375	0.25	0.9	1.65	5.5
1' - 2'	0.725	0.15	0.125	0.45	0.1	1.55
Station 2						
<0.5'	13.25	2.1	3.475		12.225	31.05
0.5 - 1'	2.325	0.375	0.25		1.65	4.6
1' - 2'	0.625	0.15	0.125		0.1	1.0
>2'	0.1					0.1
Station 3						
<0.5'	13.25	2.1			12.225	27.575
0.5 - 1'	2.325	0.525			1.65	4.5
1' - 2'	0.725				0.1	0.825

6.0 REFERENCES

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APPENDIX

SUPPLEMENTAL INFORMATION - BLAIR WATERWAY

WINTER STUDY RESULTS - BLAIR WATERWAY

Drogue trajectories obtained in the concentrated winter study in Blair Waterway are presented in the figures as follows:

Figure 16-0 = outer segment, first half small rising tide
Figure 16-M = middle segment, first half small rising tide
Figure 16-I = inner segment, first half small rising tide

Figure 17-0 = outer segment, last half small rising tide
Figure 17-M = middle segment, last half small rising tide
Figure 17-I = inner segment, last half small rising tide

Figure 18-0 = outer segment, first half large falling tide
Figure 18-M = middle segment, first half large falling tide
Figure 18-I = inner segment, first half large falling tide

Figure 19-0 = outer segment, last half large falling tide
Figure 19-M = middle segment, last half large falling tide
Figure 19-I = inner segment, last half large falling tide

Figure 20-0 = outer segment, first half large rising tide
Figure 20-M = middle segment, first half large rising tide
Figure 20-I = inner segment, first half large rising tide

Figure 21-0 = outer segment, last half large rising tide
Figure 21-M = middle segment, last half large rising tide

Figure 22-0 = outer segment, first half small falling tide
Figure 22-M = middle segment, first half small falling tide
Figure 22-I = inner segment, first half small falling tide

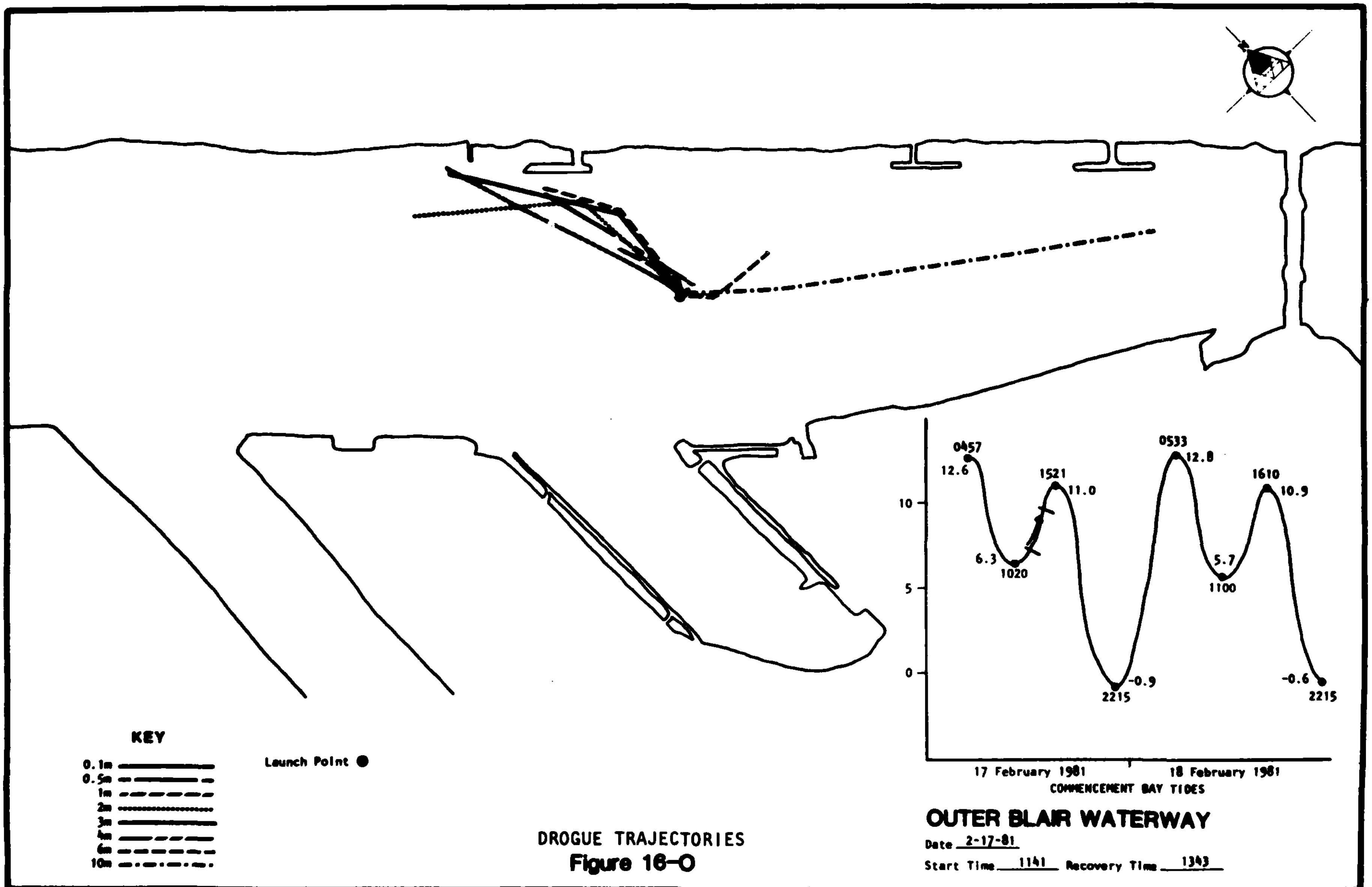
Figure 23-0 = outer segment, last half small falling tide
Figure 23-M = middle segment, last half small falling tide
Figure 23-I = inner segment, last half small falling tide

Figure 24-0 = outer segment, first half small rising tide
Figure 24-M = middle segment, first half small rising tide

The coding of the figure numbers is such that any given number represents a particular half of a tide, and the letter O, M, or I represents the outer, middle, or inner segment of the waterway.

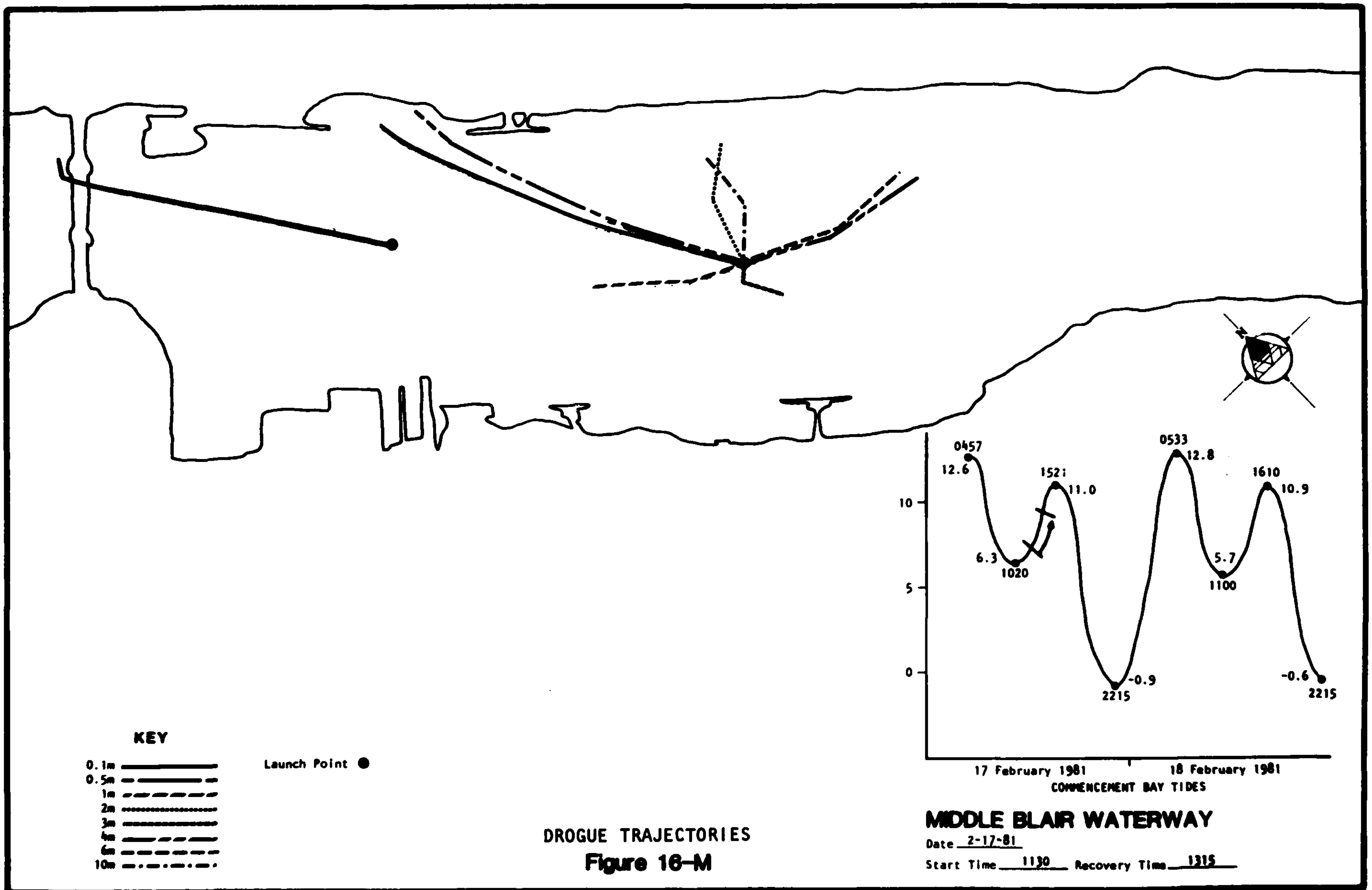
Tables 2.16 through 2.24 present observed speeds and directions for drogues within Blair Waterway with the numbers after the decimals keyed to the number of the corresponding figure. The tables are broken down to outer, middle, and inner segments.

Current profiles and average longitudinal speeds obtained on consecutive small and large falling and rising tides on February 17 - 18, 1981 for the inner, middle, and outer segments of Blair Waterway are presented in Figures 25.16 through 25.24. The numbers after the decimal are keyed to the trajectory figure numbers of 16 through 24.

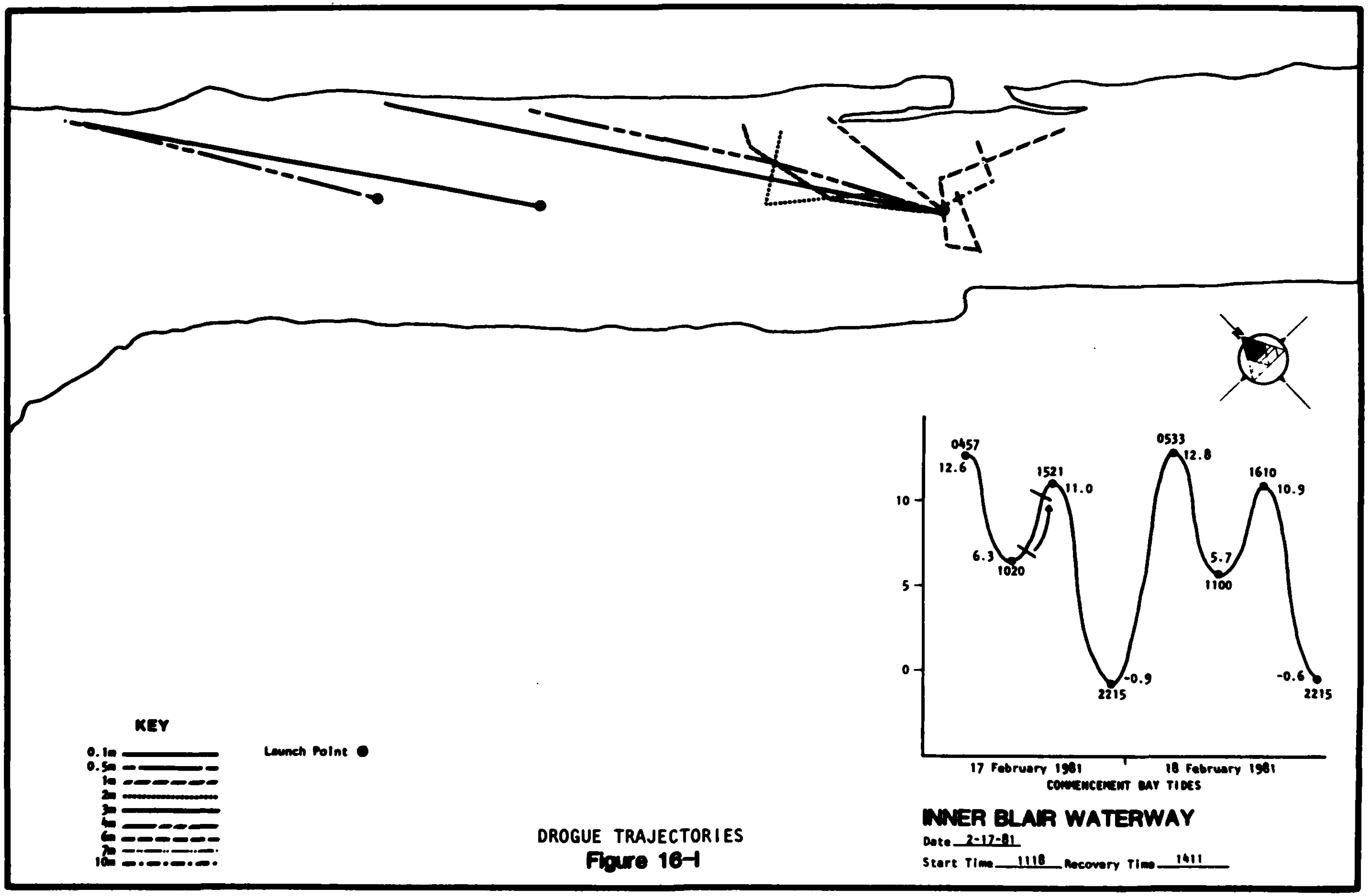


DROGUE TRAJECTORIES

Figure 16-O

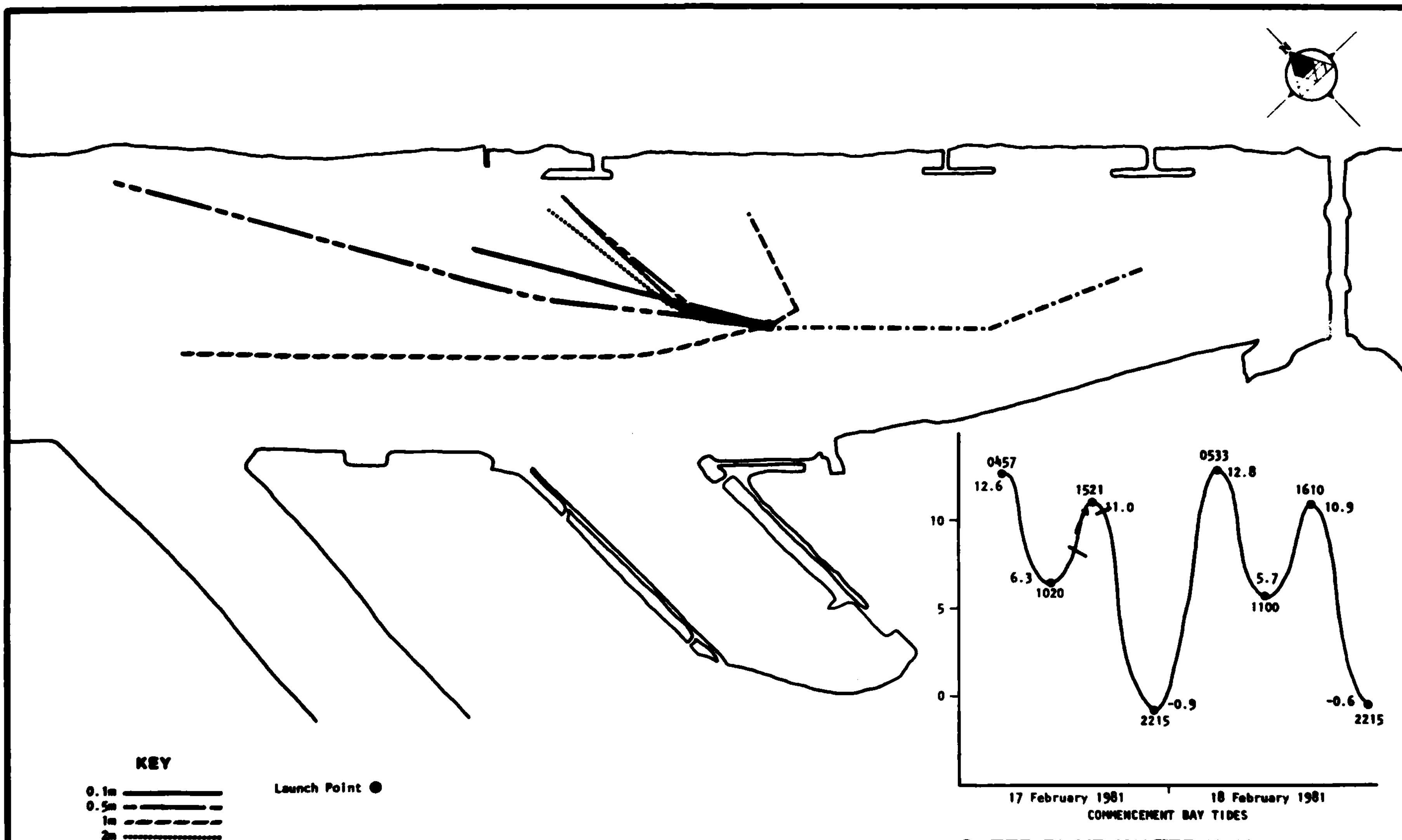


DROGUE TRAJECTORIES
Figure 16-M



DROGUE TRAJECTORIES

Figure 16-1

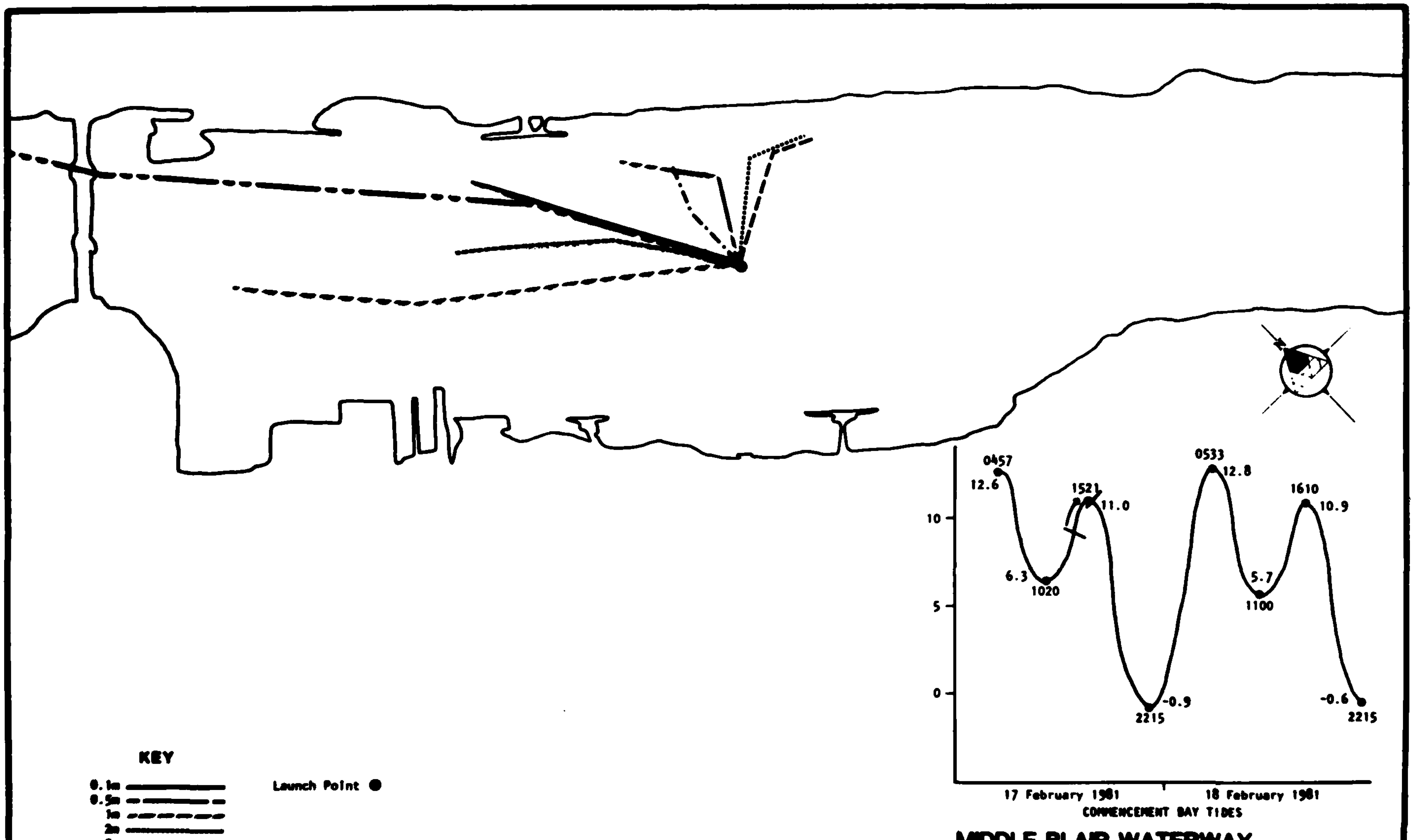


DROGUE TRAJECTORIES
Figure 17-O

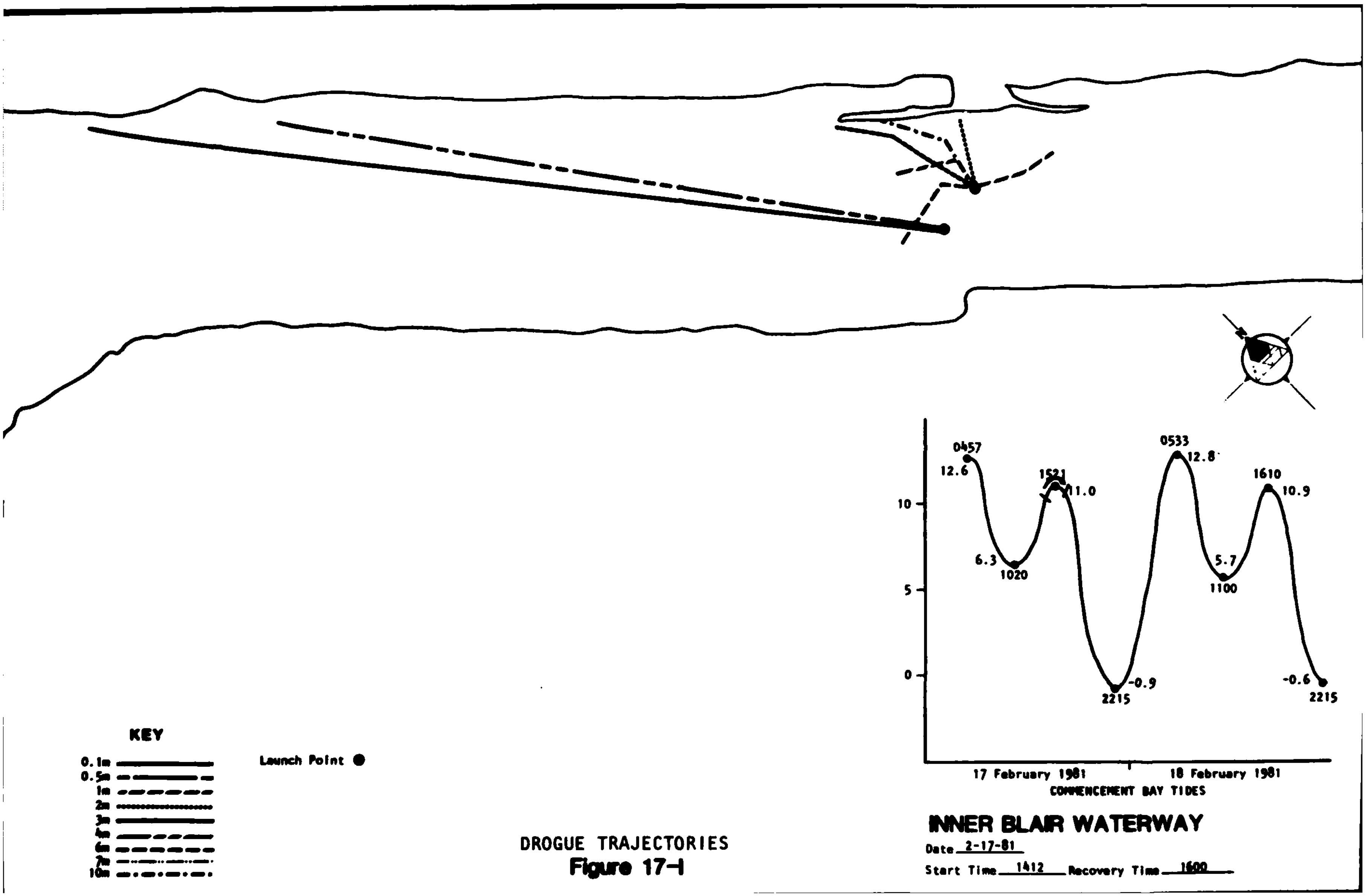
OUTER BLAIR WATERWAY

Date 2-17-81

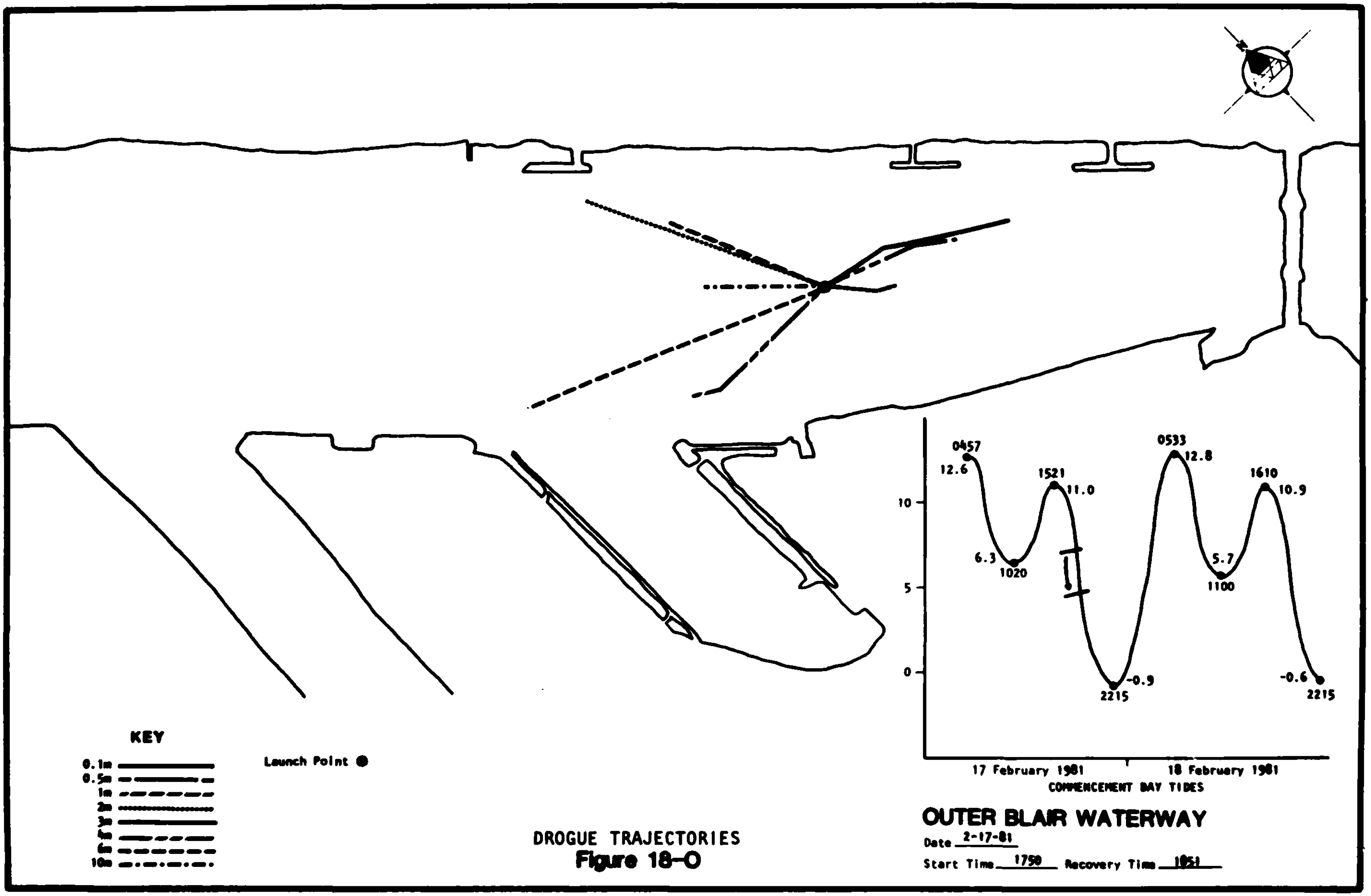
Start Time 1345 Recovery Time 1542



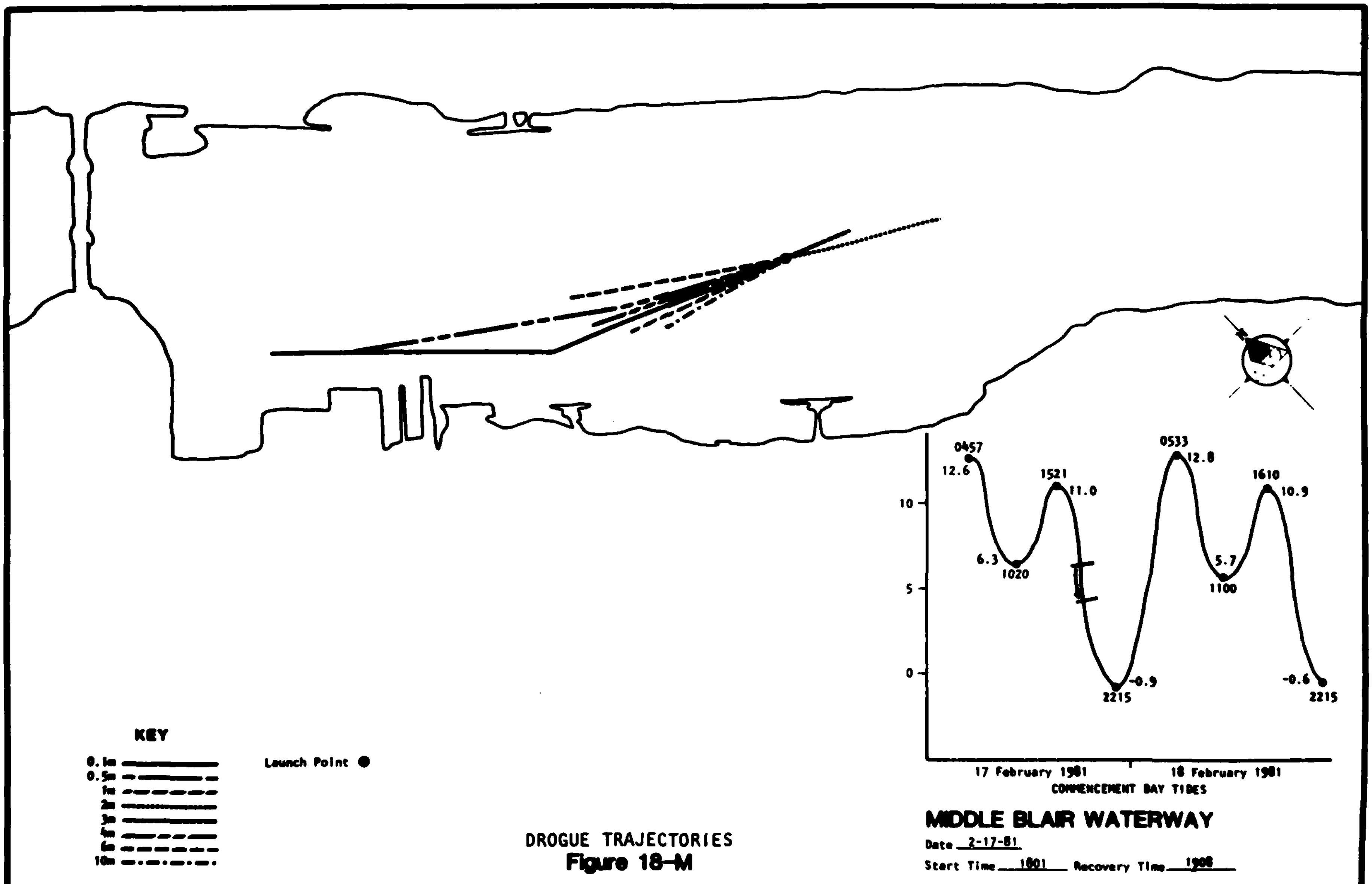
DROGUE TRAJECTORIES
Figure 17-M



DROGUE TRAJECTORIES
Figure 17-1



DROGUE TRAJECTORIES
Figure 18-O



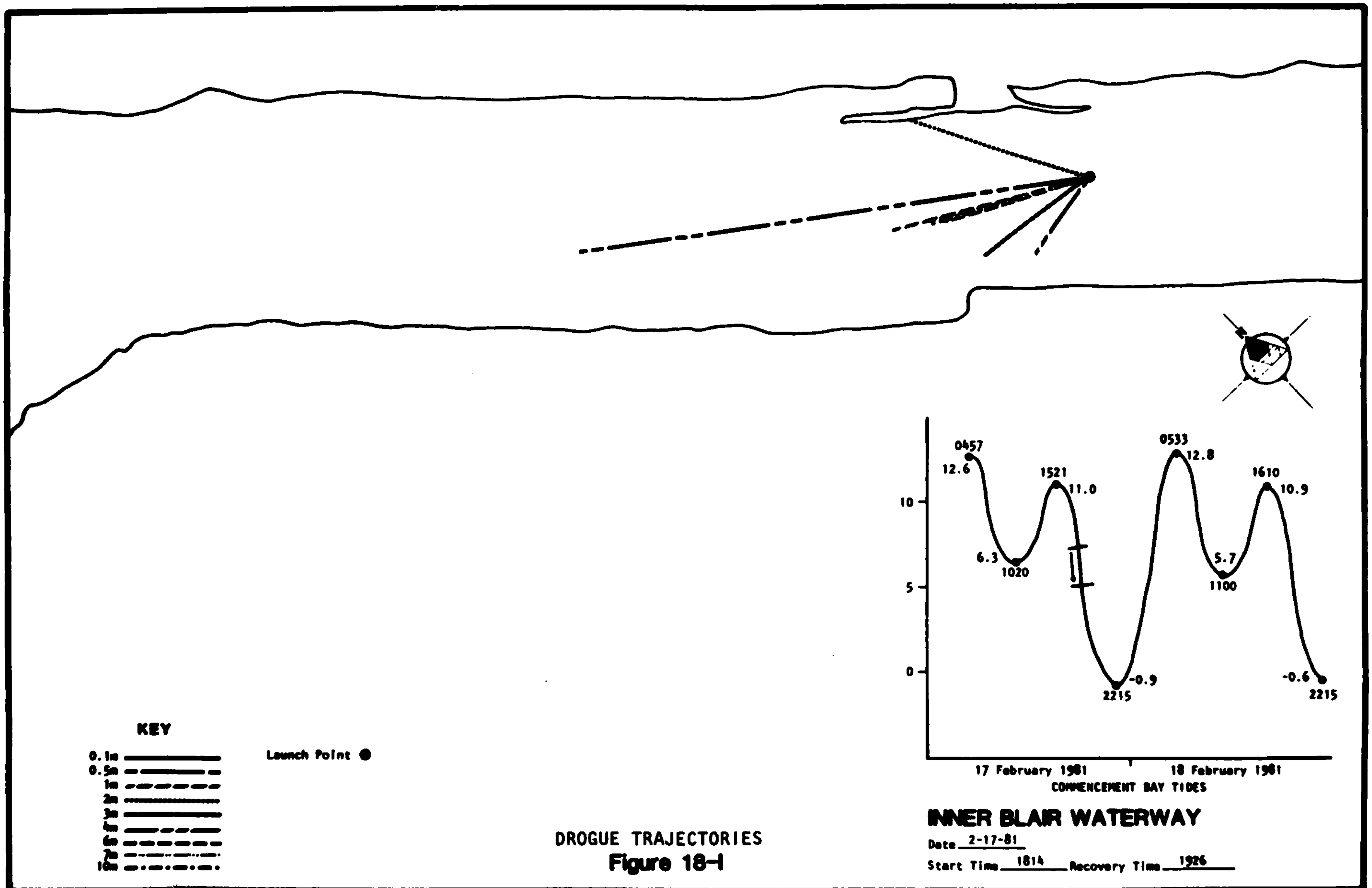
DROGUE TRAJECTORIES

Figure 18–M

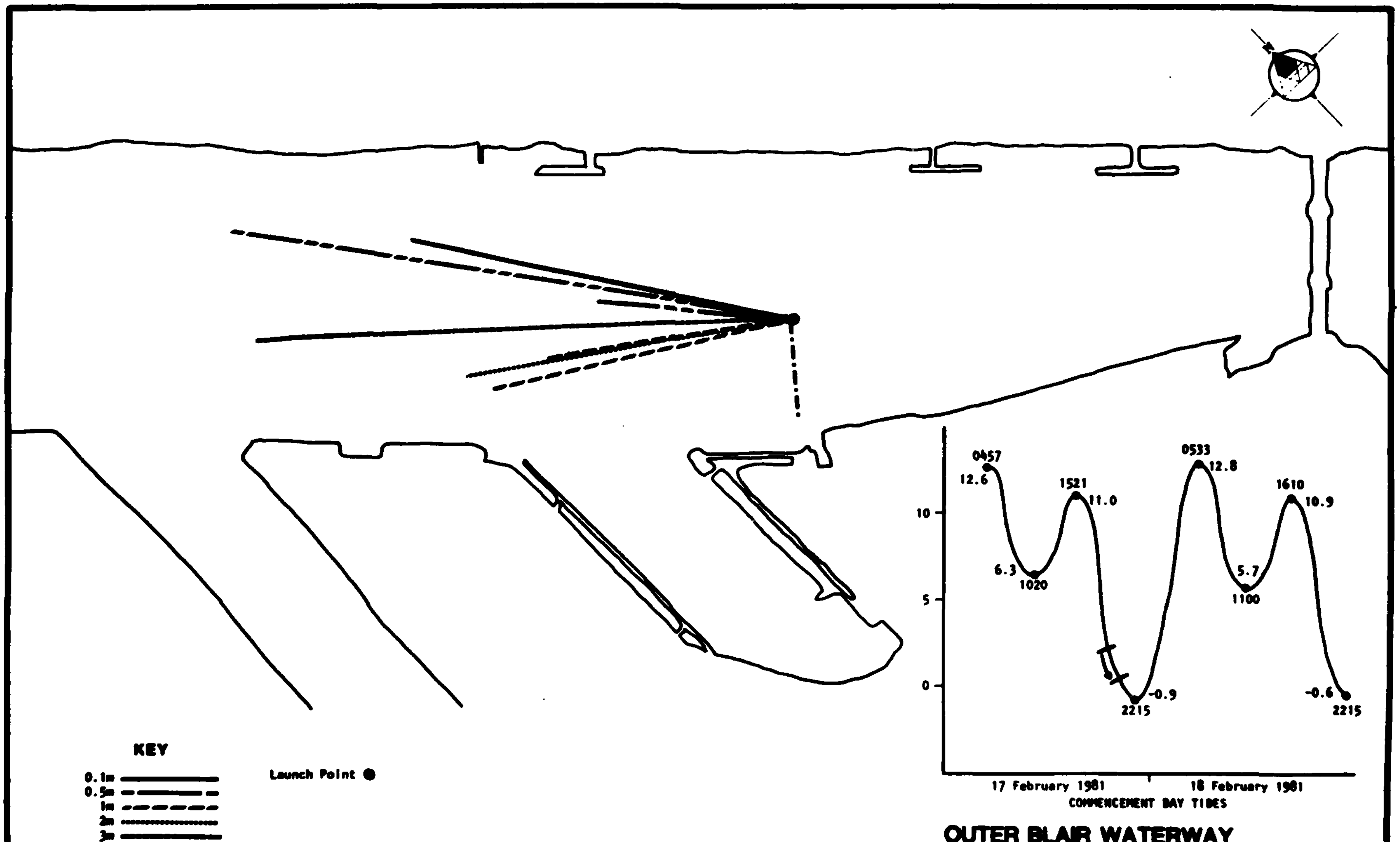
MIDDLE BLAIR WATERWAY

Date 2-17-81

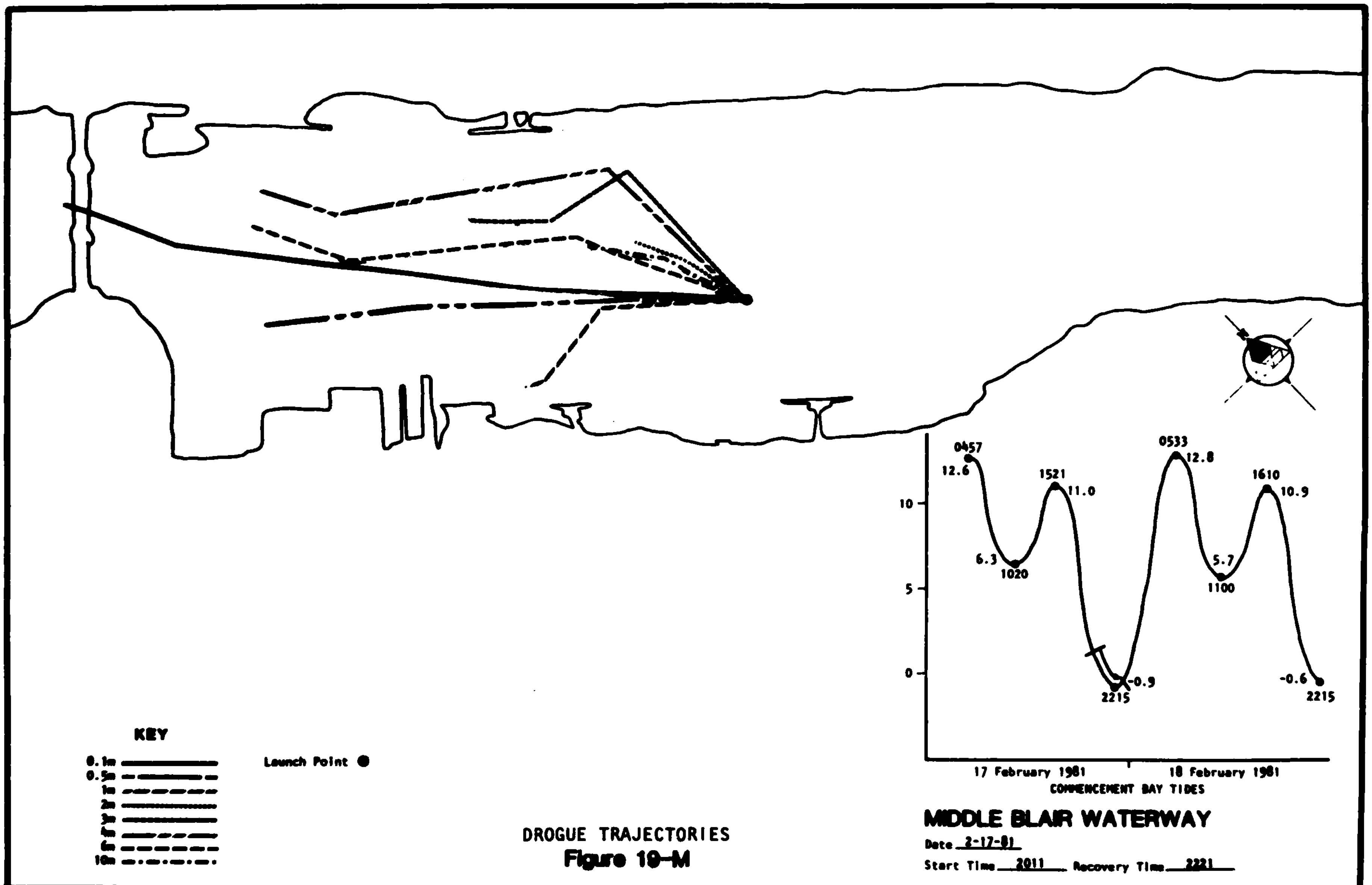
Start Time 1801 Recovery Time 1908



DROGUE TRAJECTORIES
Figure 18-1

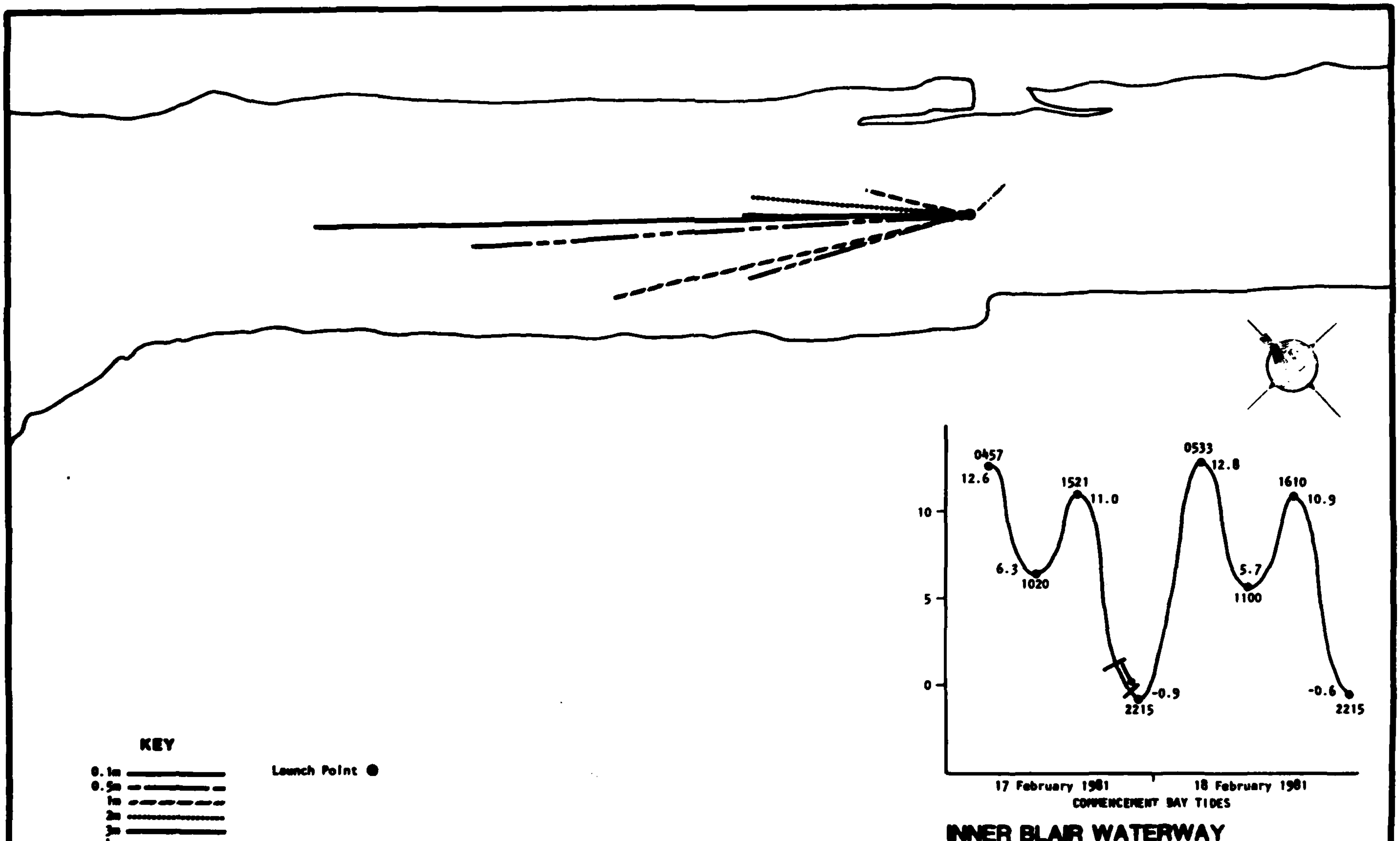


DROGUE TRAJECTORIES
Figure 19-O

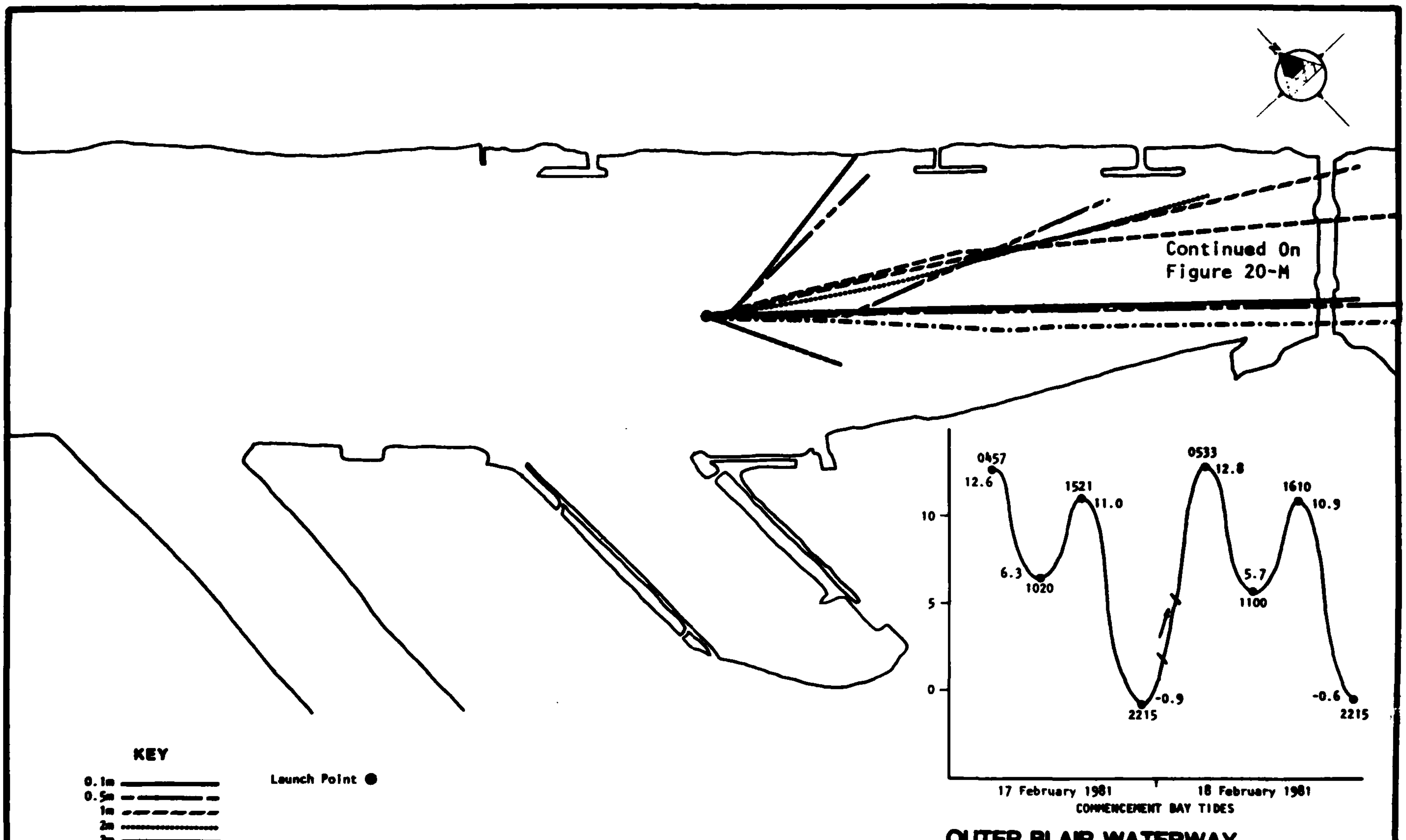


DROGUE TRAJECTORIES

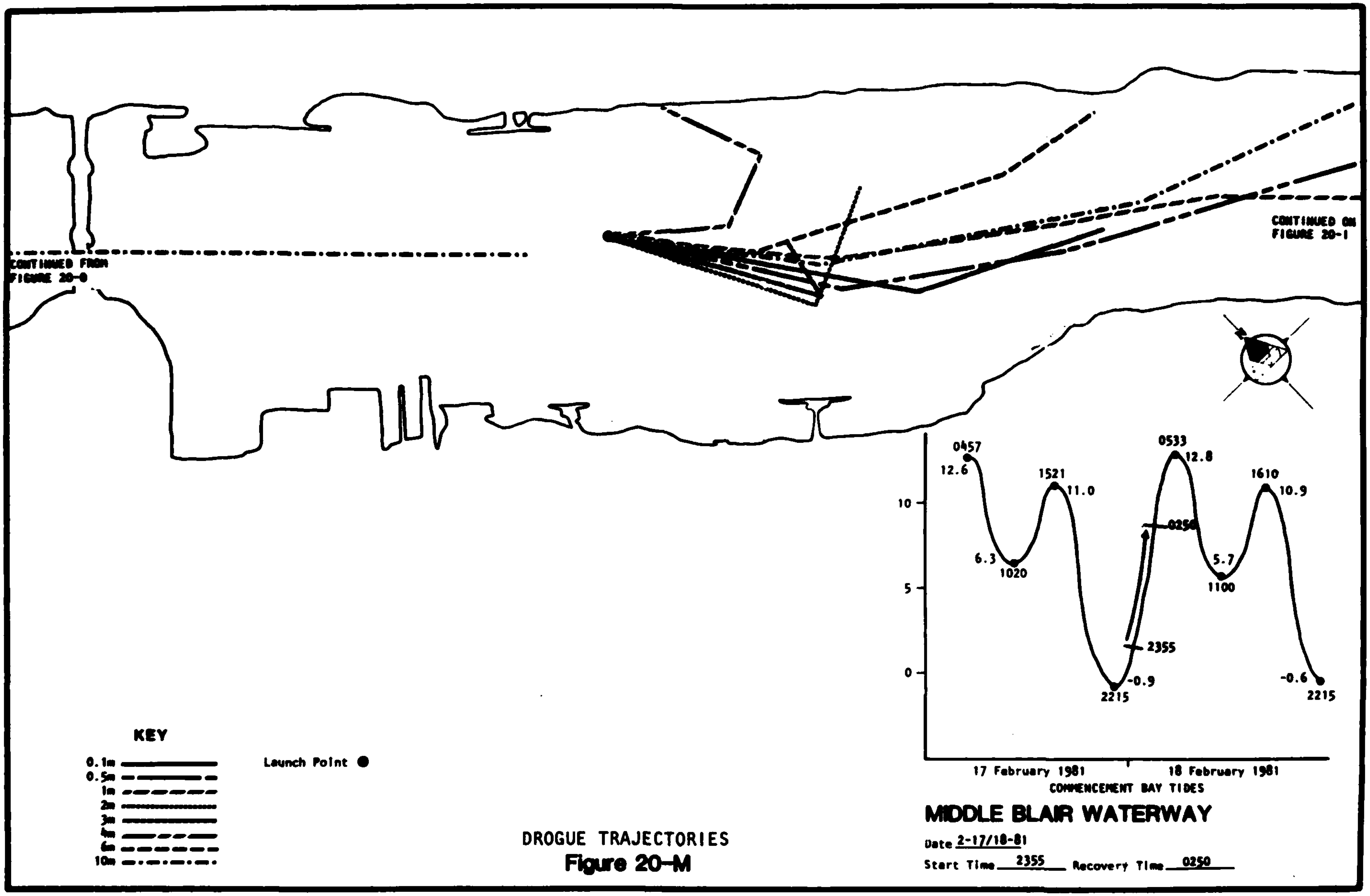
Figure 19-M



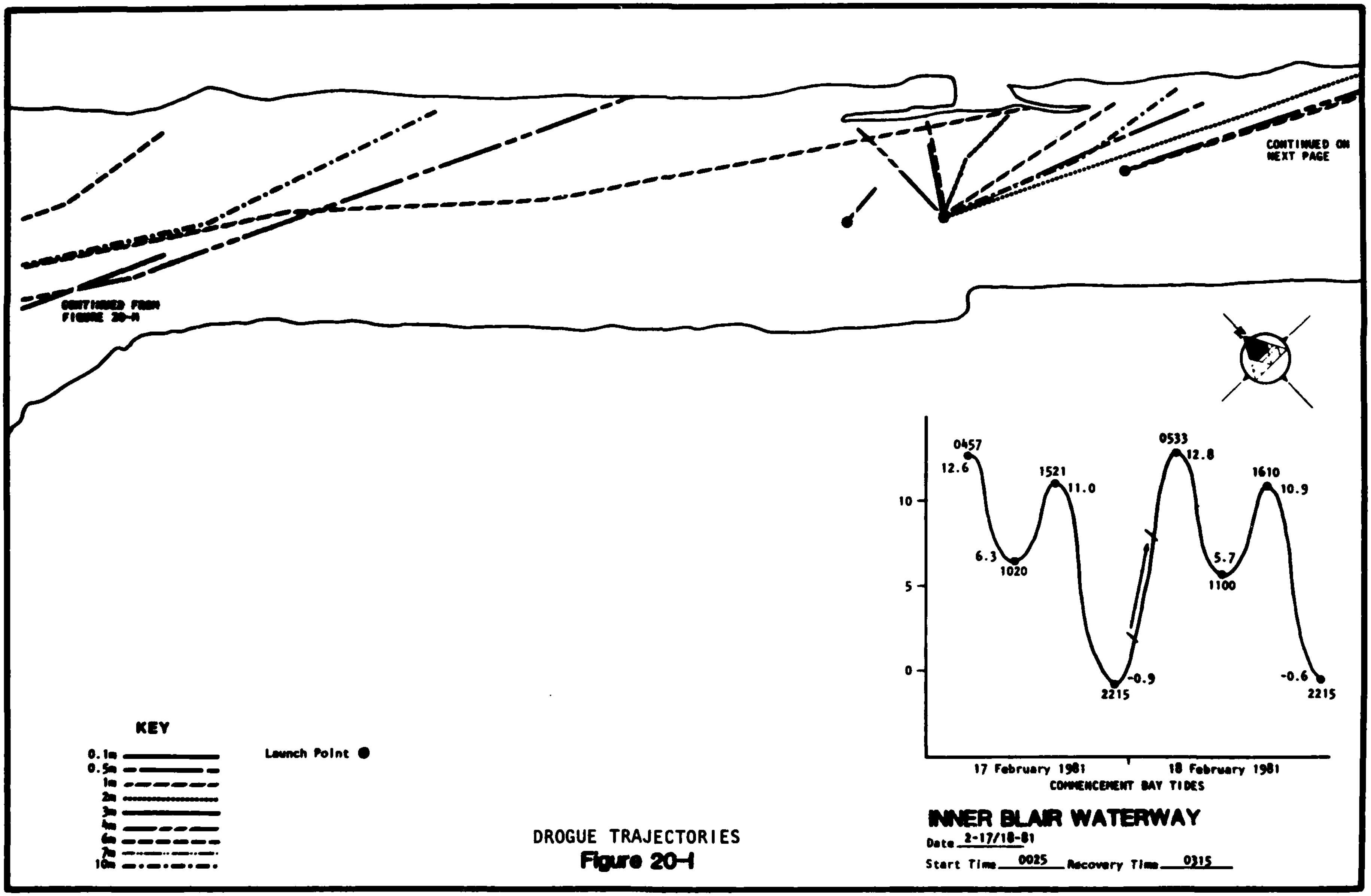
DROGUE TRAJECTORIES
Figure 19-1



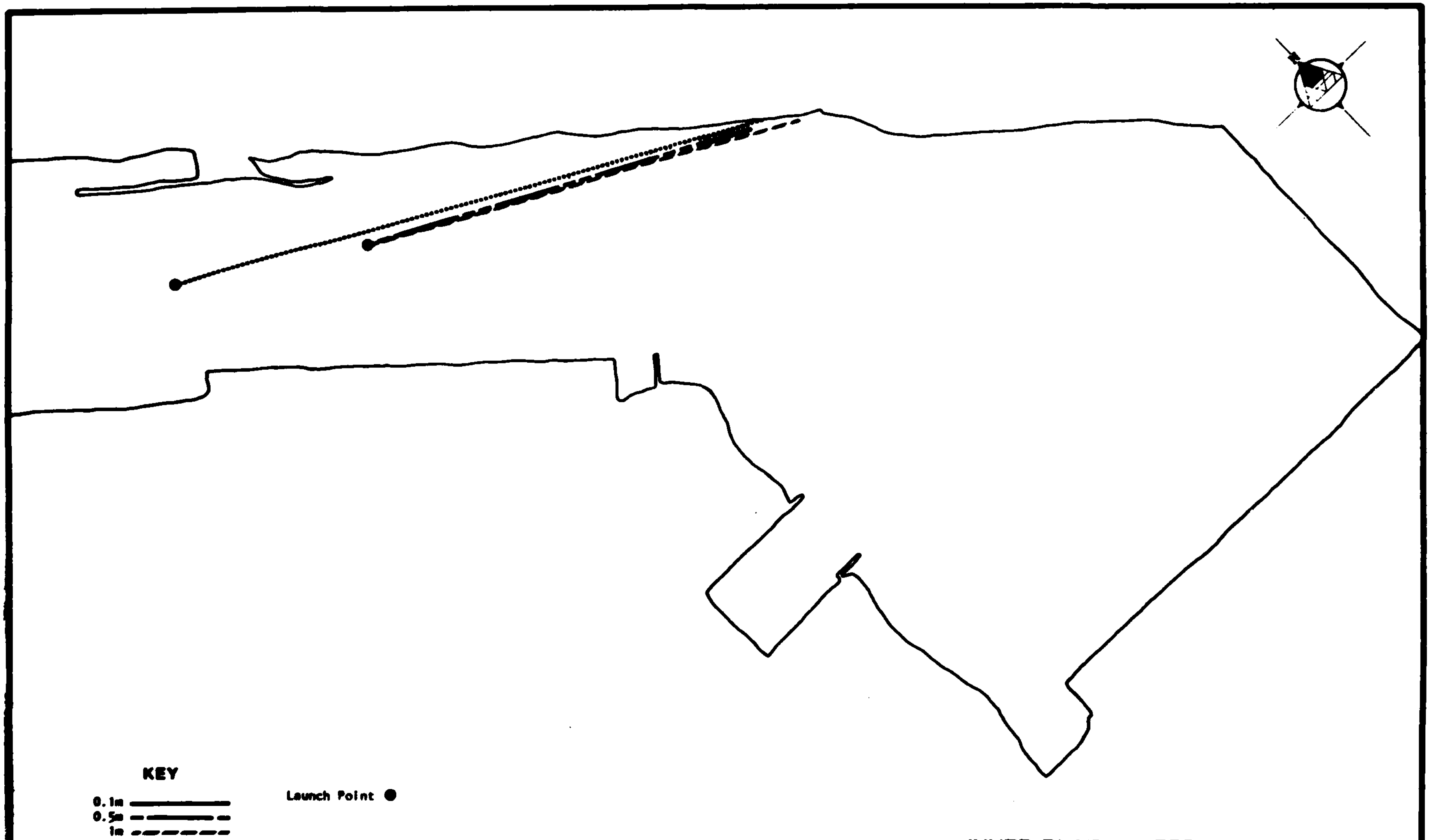
DROGUE TRAJECTORIES
Figure 20-O



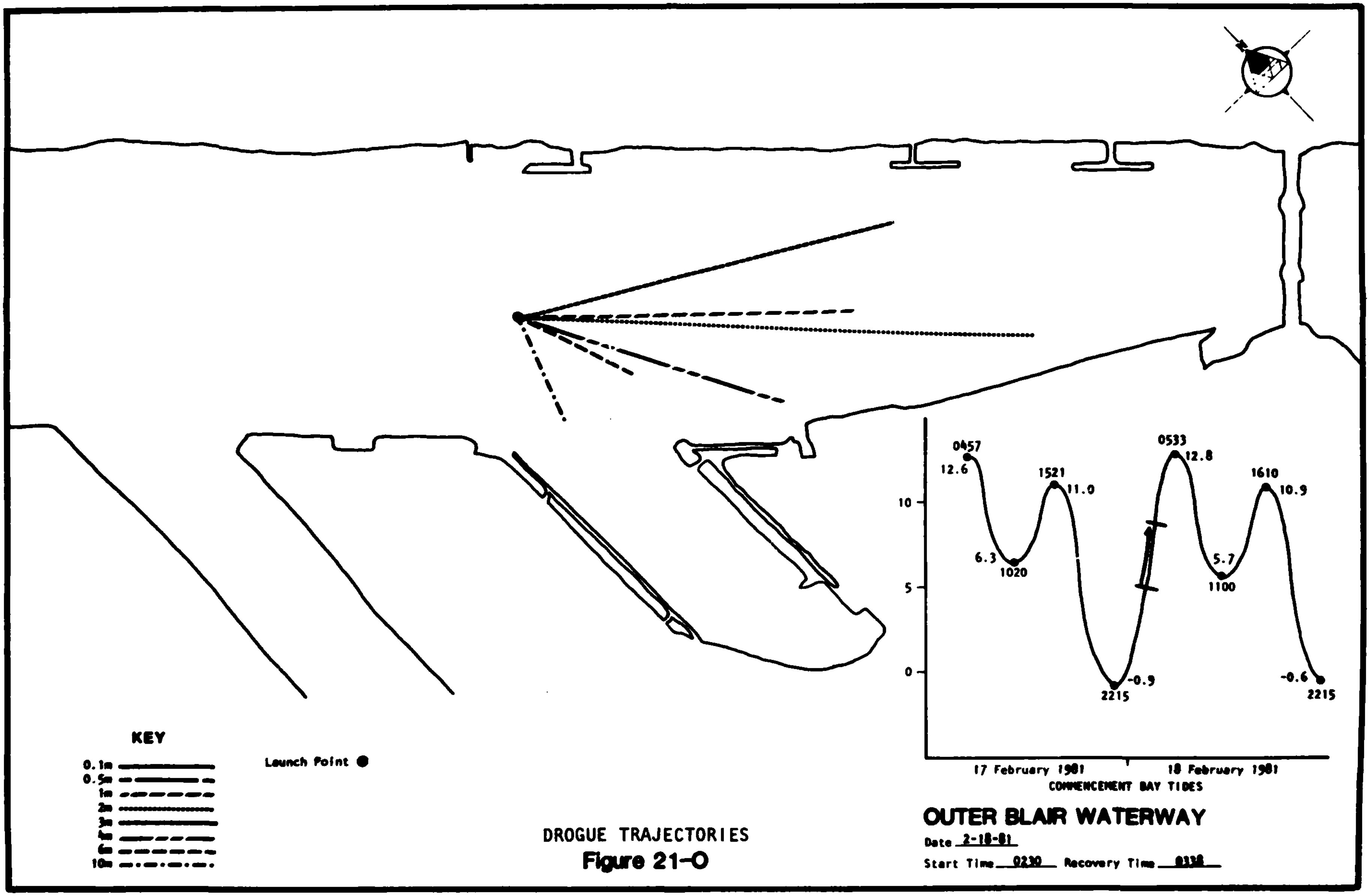
DROGUE TRAJECTORIES
Figure 20-M



DROGUE TRAJECTORIES
Figure 20-I

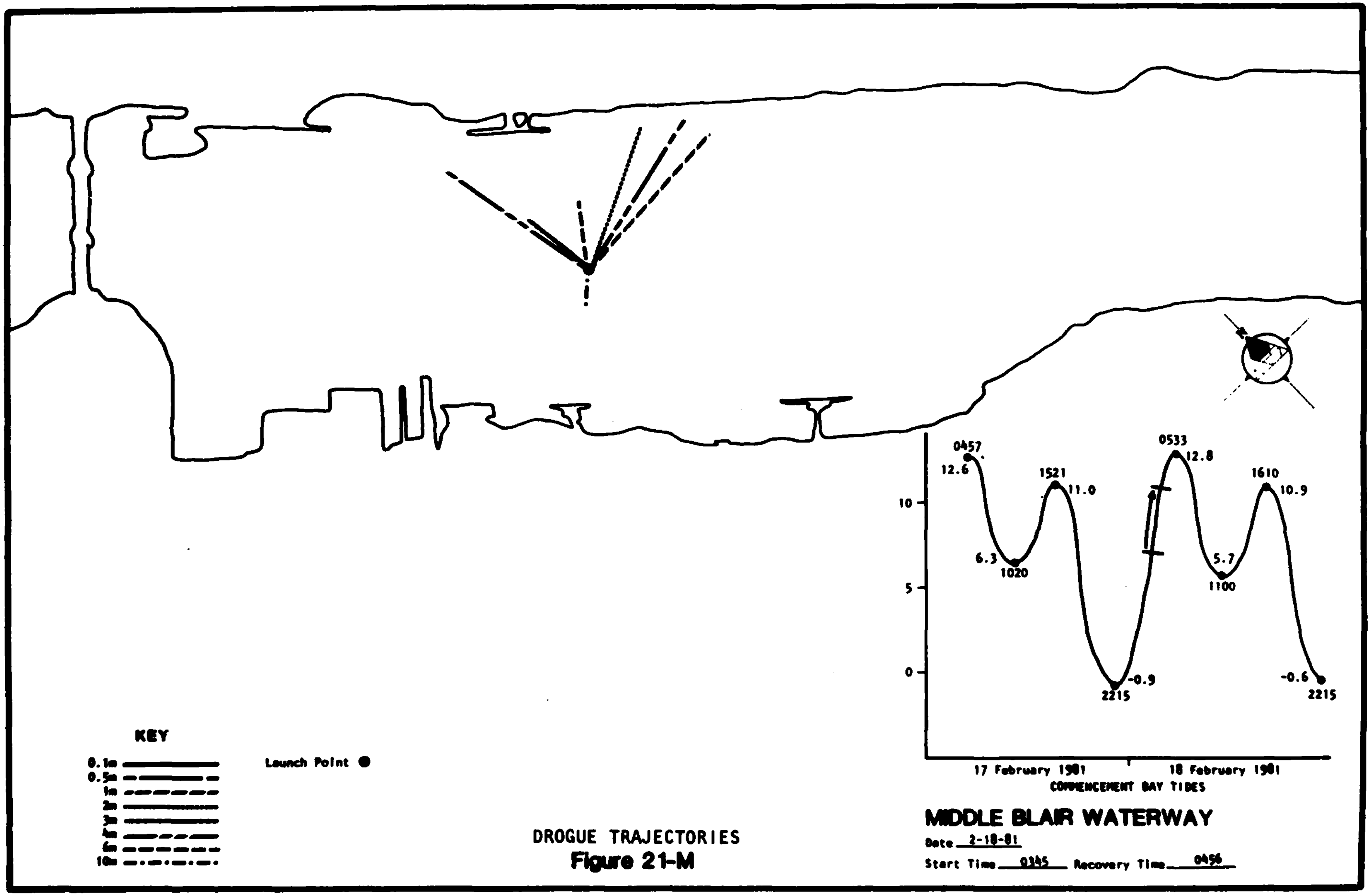


DROGUE TRAJECTORIES
Figure 20-I (Cont)



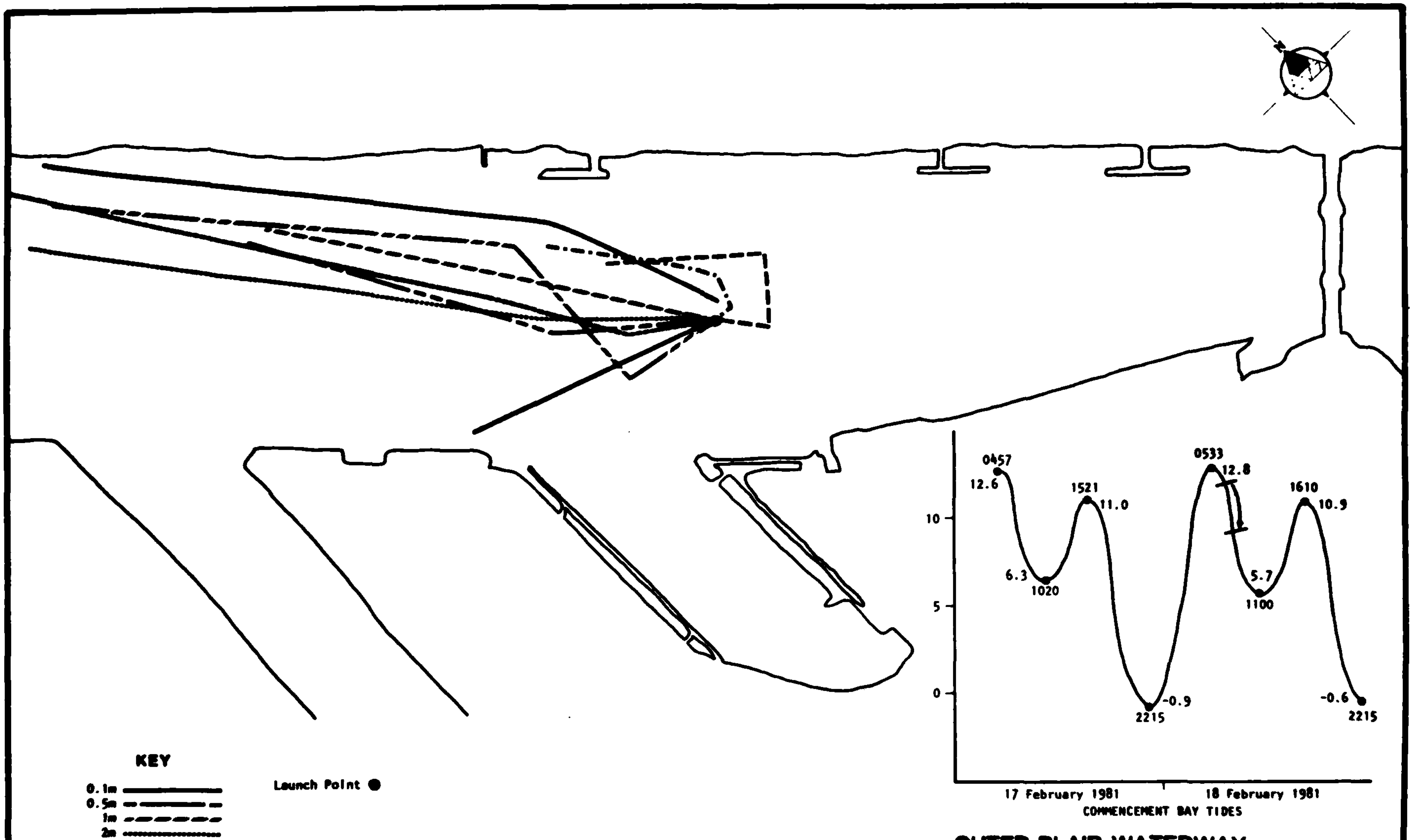
DROGUE TRAJECTORIES

Figure 21-O

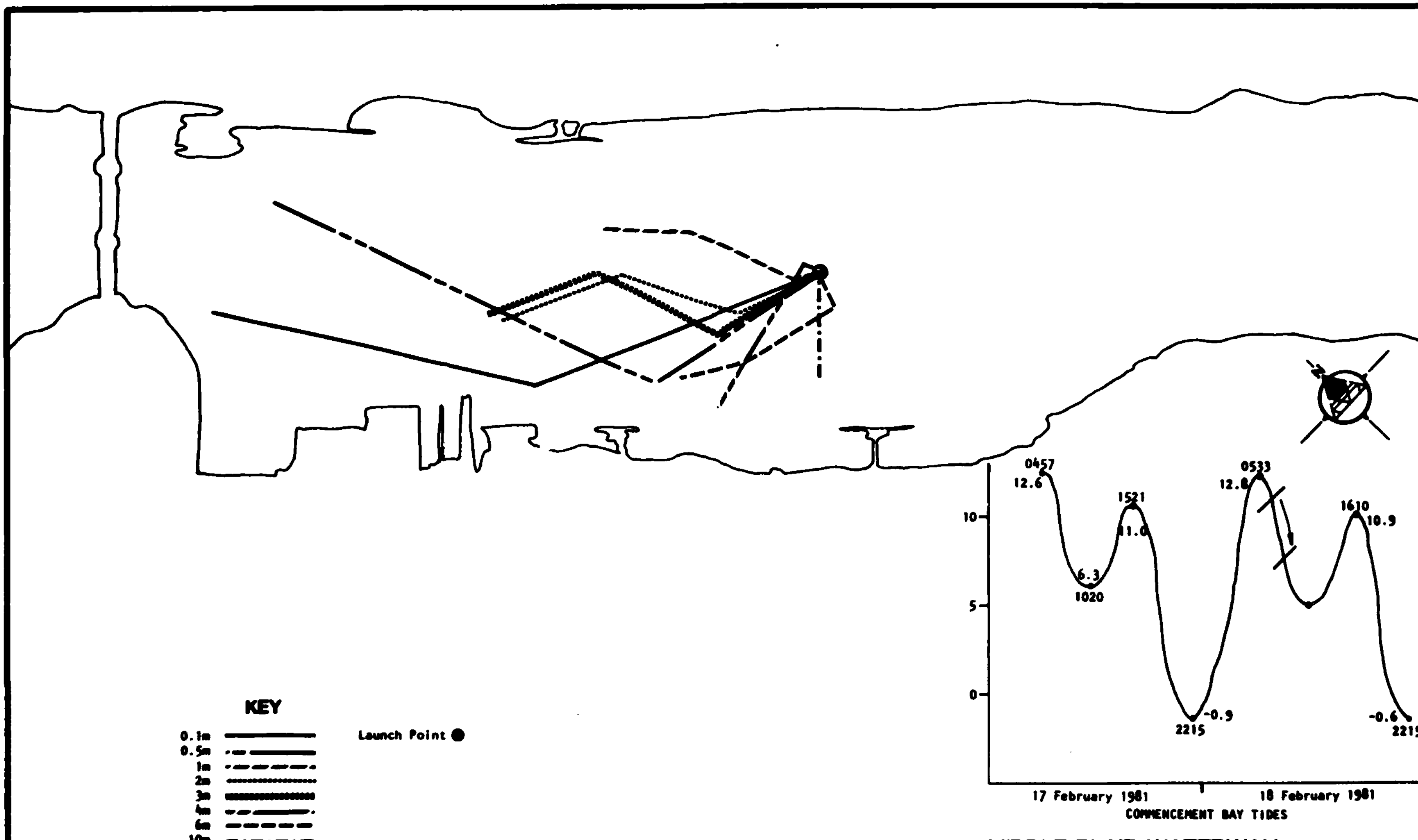


DROGUE TRAJECTORIES
Figure 21-M

NOTE: NO 21-L OBSERVATIONS WERE MADE.



DROGUE TRAJECTORIES
Figure 22-O



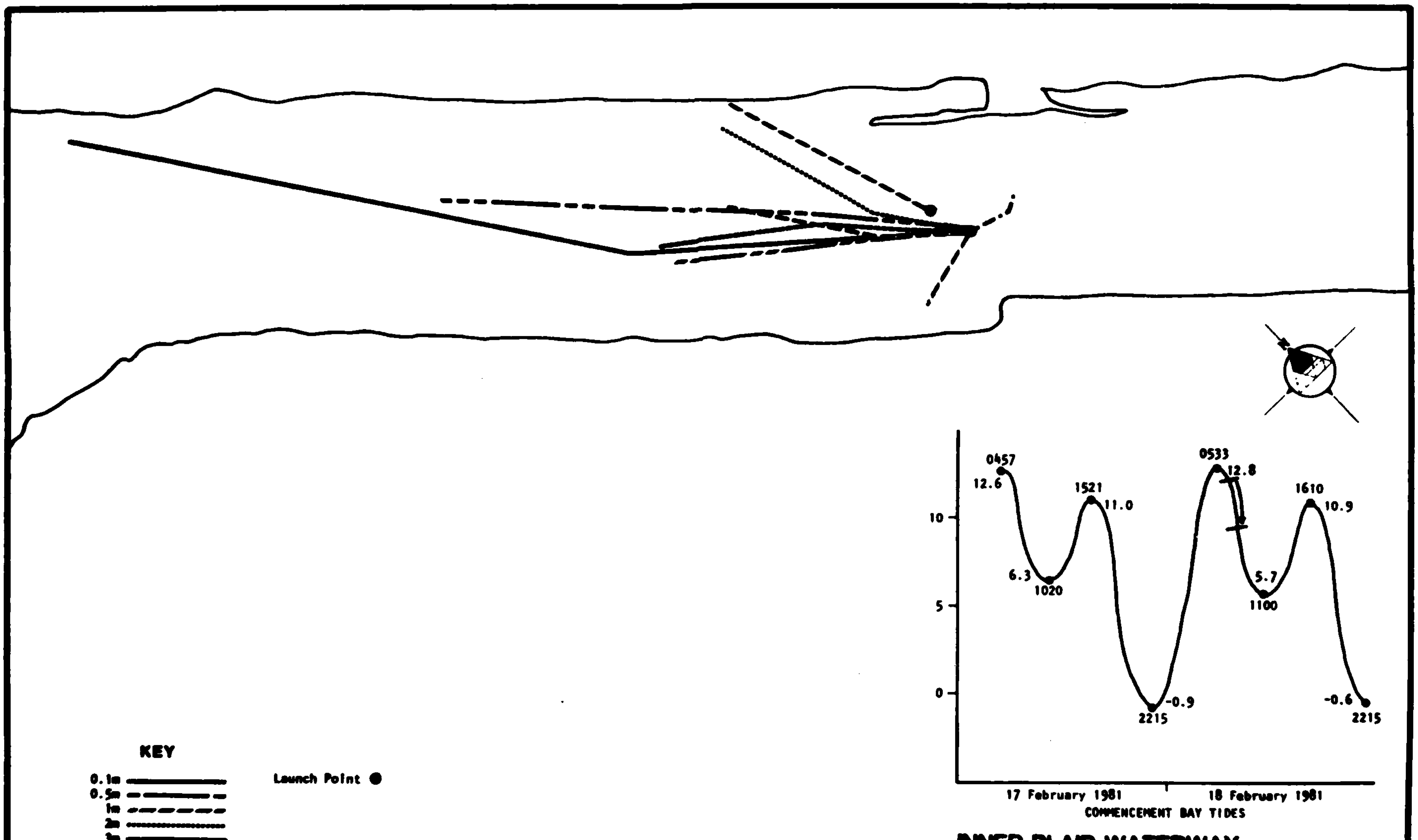
MIDDLE BLAIR WATERWAY

Date 2-18-81

Start Time 0645 Recovery Time 0841

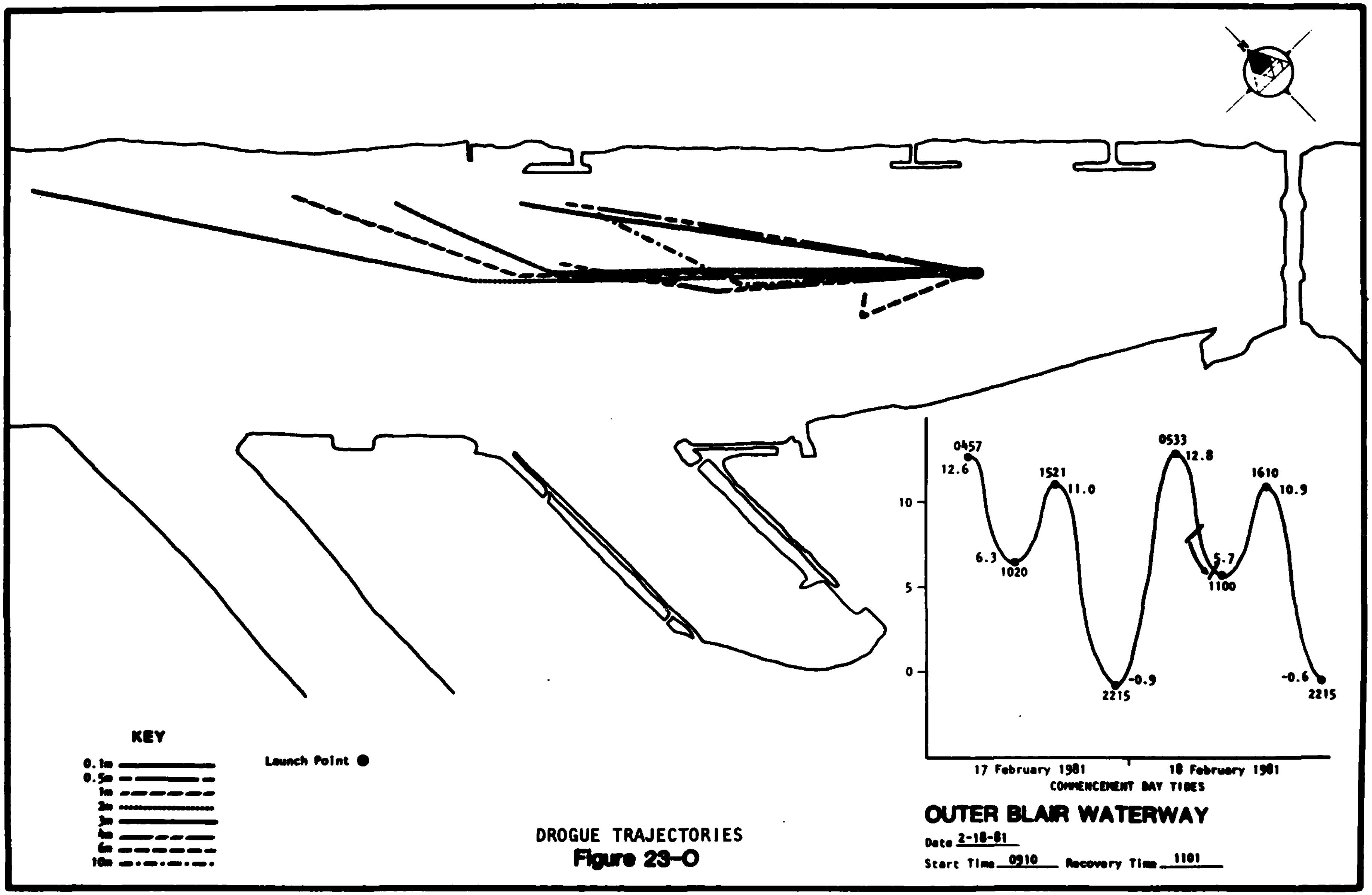
DROGUE TRAJECTORIES

FIGURE 22-M

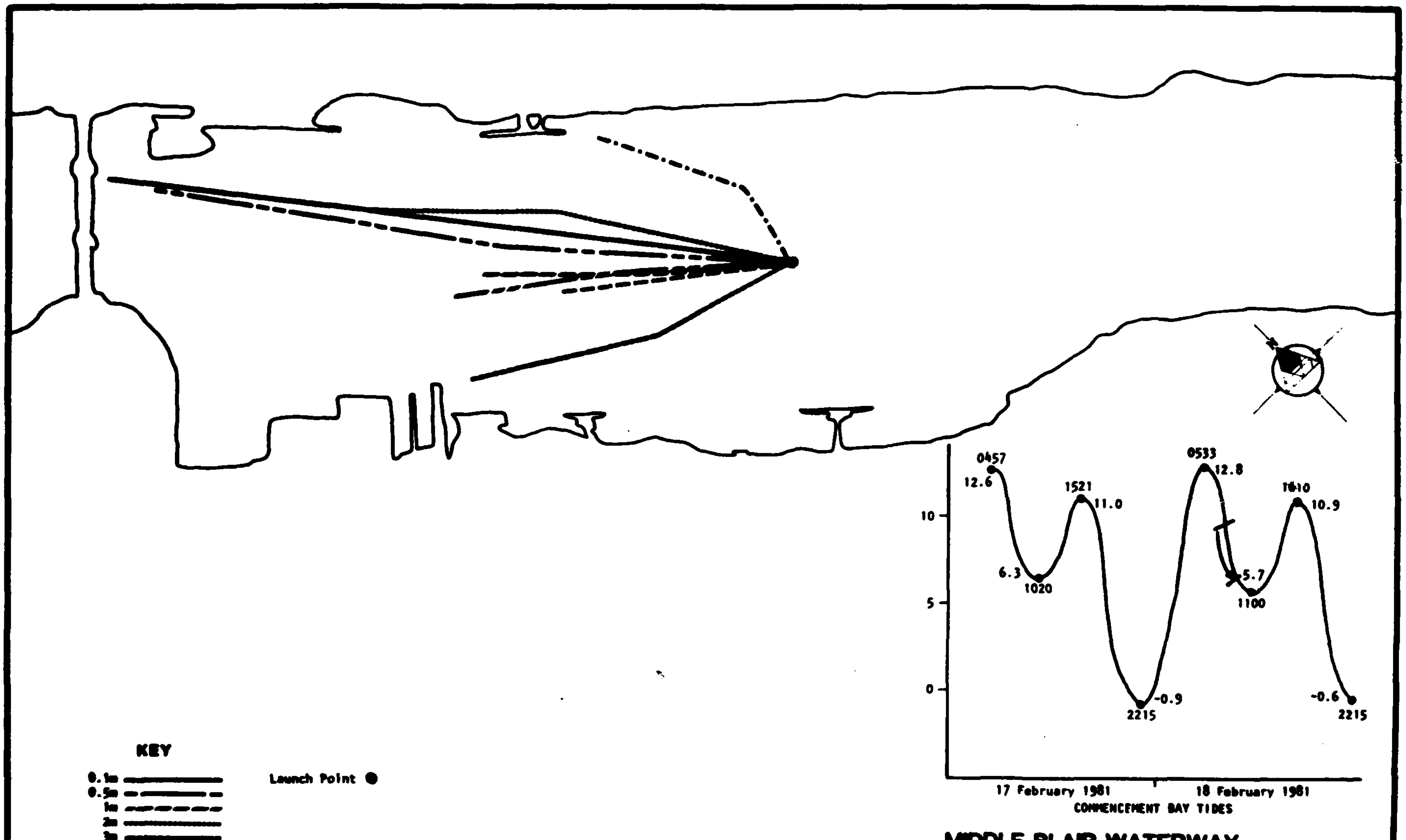


DROGUE TRAJECTORIES

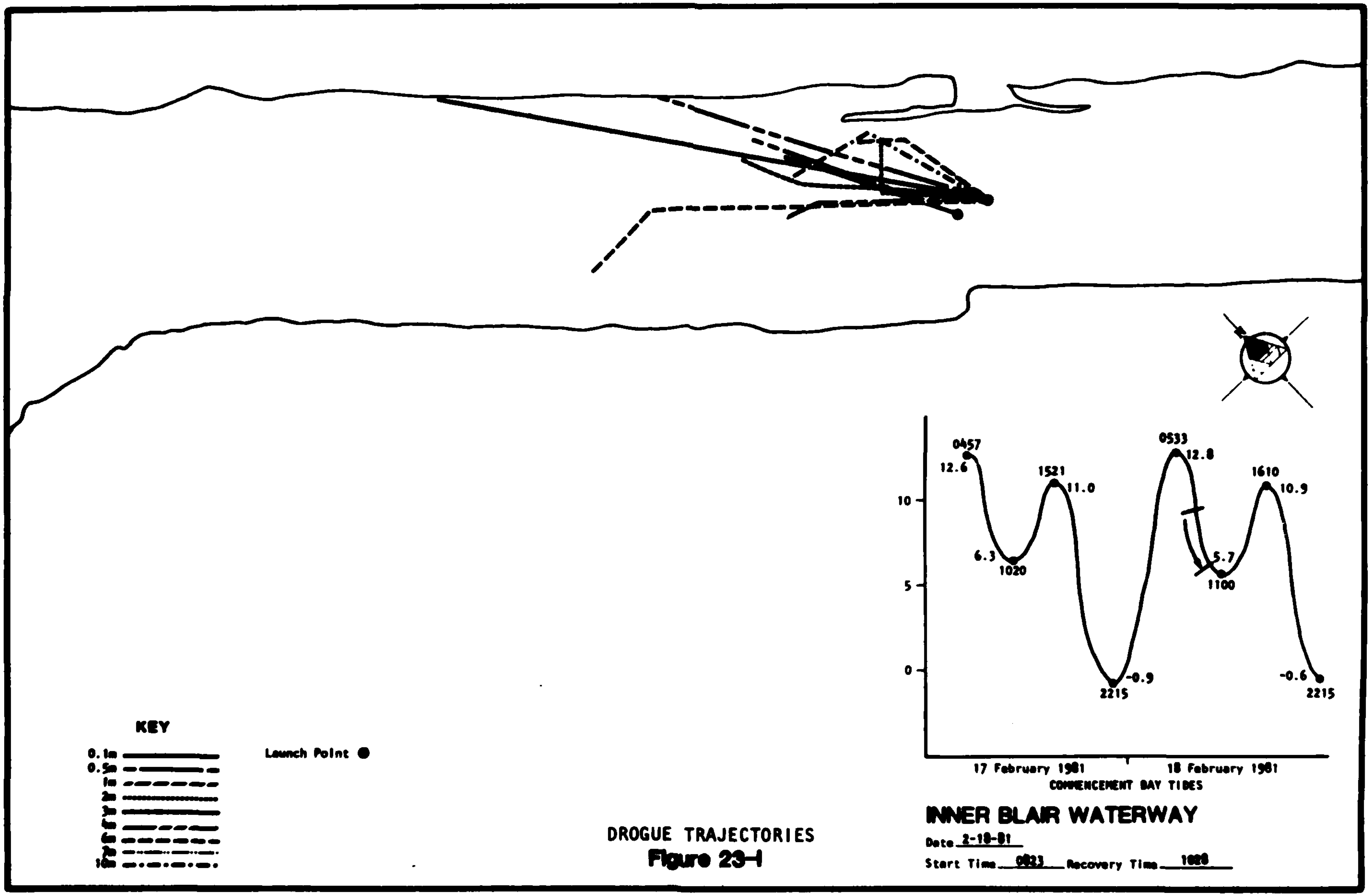
Figure 22-I



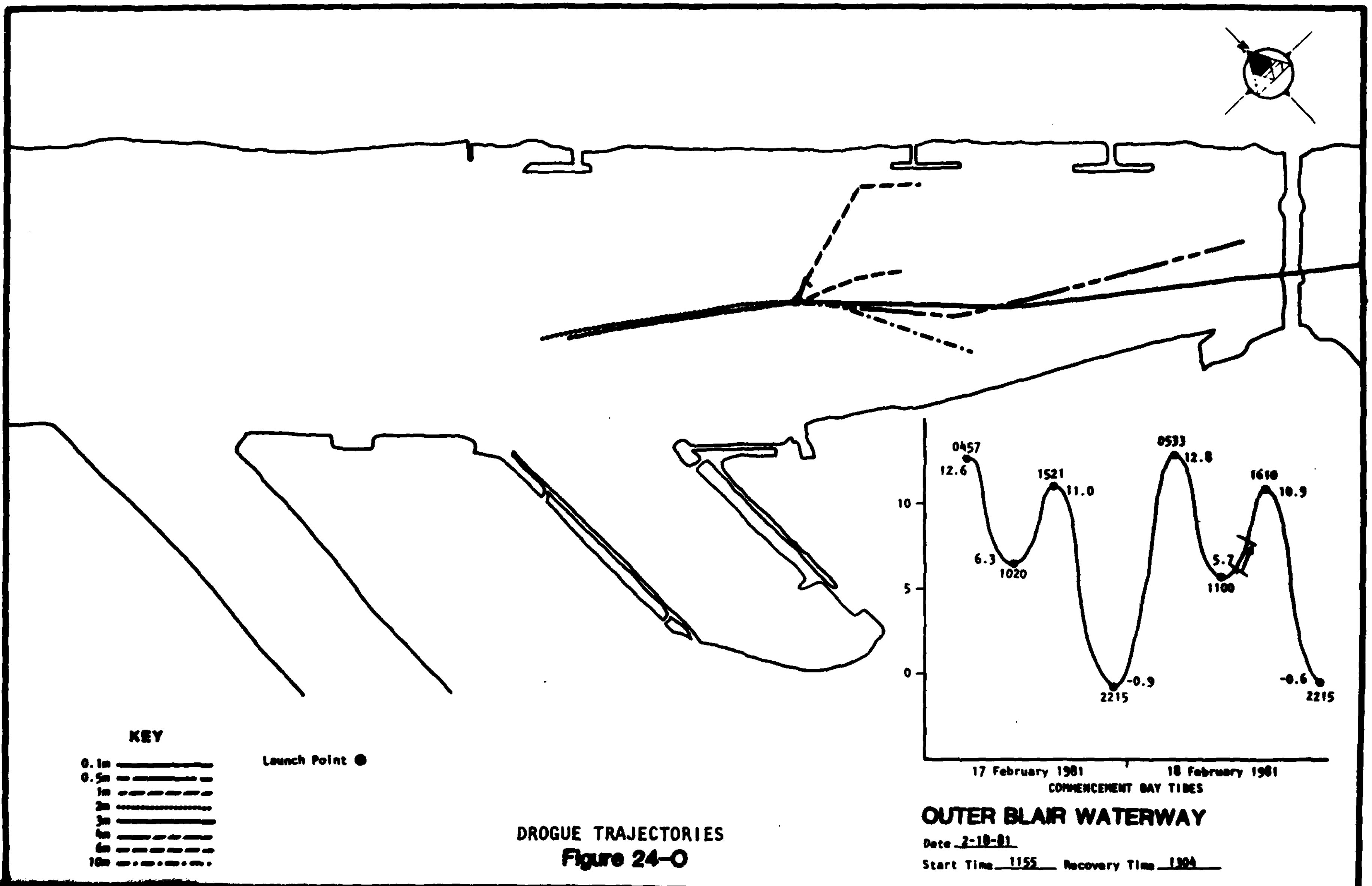
DROGUE TRAJECTORIES
Figure 23-O



DROGUE TRAJECTORIES
Figure 23-M

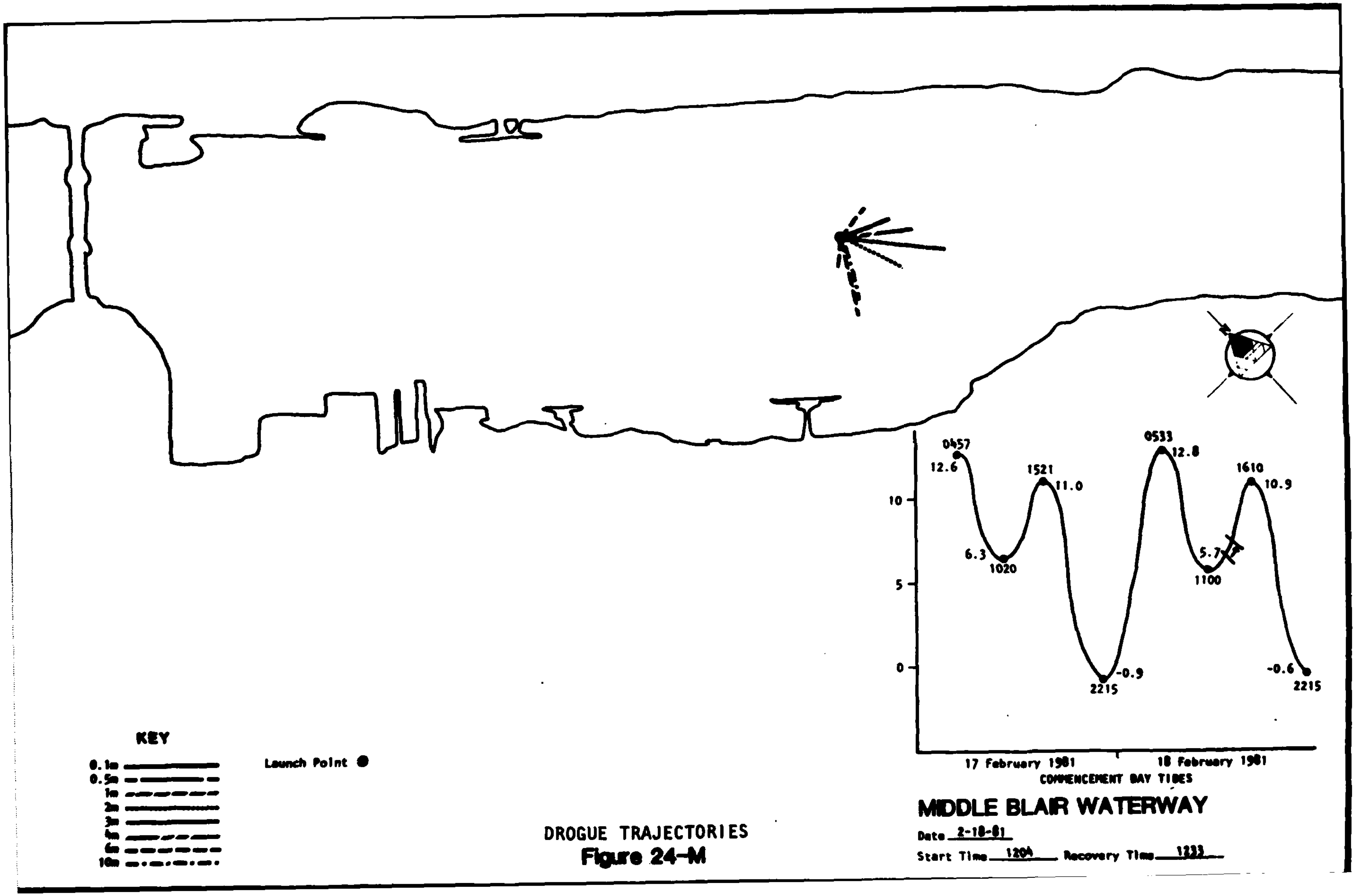


DROGUE TRAJECTORIES
Figure 23-I



DROGUE TRAJECTORIES

Figure 24-O



DROGUE TRAJECTORIES

Figure 24-M

TABLE 2.16-0

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 OUTER SET 1

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 21. MOVED 0.12 NMI IN 1.96 HRS. AVG SPD 0.06 KTS DEPTH - 0.1 M						
N	17	1141	47-16-31	122-24-25		
					0.03	342
N	47	1222	47-16-32	122-24-26		
					0.08	341
N	87	1339	47-16-38	122-24-29		
DROGUE - 57. MOVED 0.08 NMI IN 1.93 HRS. AVG SPD 0.04 KTS DEPTH - 0.5 M						
N	18	1141	47-16-31	122-24-25		
					0.00	90
N	45	1221	47-16-31	122-24-25		
					0.06	346
N	84	1337	47-16-36	122-24-26		
DROGUE - 64. MOVED 0.08 NMI IN 1.93 HRS. AVG SPD 0.04 KTS DEPTH - 1.0 M						
N	19	1141	47-16-31	122-24-25		
					0.07	6
N	49	1223	47-16-34	122-24-25		
					0.03	330
N	85	1337	47-16-36	122-24-26		
DROGUE - 73. MOVED 0.13 NMI IN 2.01 HRS. AVG SPD 0.06 KTS DEPTH - 2.0 M						
N	20	1141	47-16-31	122-24-25		
					0.09	357
N	50	1223	47-16-35	122-24-26		
					0.06	308
N	88	1342	47-16-38	122-24-31		
DROGUE - 87. MOVED 0.12 NMI IN 1.96 HRS. AVG SPD 0.06 KTS DEPTH - 3.0 M						
N	21	1141	47-16-31	122-24-25		
					0.06	7
N	48	1223	47-16-34	122-24-25		
					0.06	329
N	86	1339	47-16-38	122-24-29		
DROGUE - 92. MOVED 0.03 NMI IN 1.91 HRS. AVG SPD 0.02 KTS DEPTH - 4.0 M						
N	22	1141	47-16-31	122-24-25		
					0.01	25
N	46	1221	47-16-31	122-24-25		
					0.02	342
N	83	1336	47-16-33	122-24-26		
DROGUE - 100. MOVED 0.04 NMI IN 1.86 HRS. AVG SPD 0.02 KTS DEPTH - 6.0 M						
N	23	1141	47-16-31	122-24-25		
					0.02	142
N	44	1220	47-16-30	122-24-24		
					0.02	90
N	82	1333	47-16-30	122-24-21		

TABLE 2.16-0 (continued)

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 OUTER SET 1

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 111. MOVED 0.23 NMI IN 1.83 HRS. AVG SPD 0.12 KTS						
DEPTH - 10.0 M						
N	24	1141	47-16-31	122-24-25		
					0.06	131
N	43	1219	47-16-29	122-24-22		
					0.16	124
N	81	1331	47-16-22	122-24- 8		

TABLE 2.16-M

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 MIDDLE SET 1

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 27. MOVED 0.19 NMI IN 1.03 HRS. AVG SPD 0.18 KTS DEPTH - 0.1 M						
N	9	1130	47-16- 4	122-23-45		
					0.27	329
N	25	1148	47-16- 8	122-23-48		
					0.17	335
N	42	1215	47-16-13	122-23-51		
					0.12	343
N	51	1232	47-16-15	122-23-52		
DROGUE - 27. MOVED 0.17 NMI IN 0.58 HRS. AVG SPD 0.29 KTS DEPTH - 0.1 M						
N	52	1233	47-16-12	122-23-56		
					0.29	328
N	69	1308	47-16-21	122-24- 3		
DROGUE - 8. MOVED 0.18 NMI IN 1.58 HRS. AVG SPD 0.11 KTS DEPTH - 0.5 M						
N	10	1130	47-16- 4	122-23-45		
					0.19	330
N	26	1150	47-16- 8	122-23-48		
					0.11	339
N	41	1214	47-16-10	122-23-49		
					0.13	340
N	53	1235	47-16-13	122-23-50		
					0.05	352
N	68	1305	47-16-14	122-23-51		
DROGUE - 67. MOVED 0.07 NMI IN 1.68 HRS. AVG SPD 0.04 KTS DEPTH - 1.0 M						
N	11	1130	47-16- 4	122-23-45		
					0.04	296
N	38	1210	47-16- 5	122-23-47		
					0.04	309
N	70	1311	47-16- 7	122-23-50		
DROGUE - 72. MOVED 0.05 NMI IN 1.53 HRS. AVG SPD 0.03 KTS DEPTH - 2.0 M						
N	12	1130	47-16- 4	122-23-45		
					0.04	17
N	39	1211	47-16- 6	122-23-44		
					0.03	53
N	67	1302	47-16- 7	122-23-42		
DROGUE - 81. MOVED 0.02 NMI IN 1.48 HRS. AVG SPD 0.01 KTS DEPTH - 3.0 M						
N	13	1130	47-16- 4	122-23-45		
					0.01	224
N	37	1209	47-16- 4	122-23-45		
					0.02	154
N	65	1259	47-16- 3	122-23-44		
DROGUE - 93. MOVED 0.09 NMI IN 1.75 HRS. AVG SPD 0.05 KTS DEPTH - 4.0 M						
N	14	1130	47-16- 4	122-23-45		
					0.07	120
N	36	1208	47-16- 3	122-23-41		
					0.04	100
N	72	1315	47-16- 2	122-23-37		

TABLE 2.16-M (continued)

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 MIDDLE SET 1

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 102. MOVED 0.08 NMI IN 1.73 HRS. AVG SPD 0.05 KTS						
DEPTH - 6.0 M						
N	15	1130	47-16- 4	122-23-45		
					0.07	116
N	35	1208	47-16- 3	122-23-41		
					0.03	94
N	71	1314	47-16- 3	122-23-37		
DROGUE - 113. MOVED 0.05 NMI IN 1.51 HRS. AVG SPD 0.03 KTS						
DEPTH - 10.0 M						
N	16	1130	47-16- 4	122-23-45		
					0.03	45
N	40	1212	47-16- 5	122-23-43		
					0.03	6
N	66	1301	47-16- 7	122-23-43		

TABLE 2.16-I

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 INNER SET 1

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE = 28. MOVED 0.28 NMI IN 1.38 HRS. AVG SPD 0.20 KTS DEPTH = 0.1 M						
N	1	1119	47-15-41	122-23- 5		
					0.27	325
N	27	1155	47-15-49	122-23-13		
					0.15	325
N	54	1242	47-15-55	122-23-20		
DROGUE = 28. MOVED 0.15 NMI IN 1.26 HRS. AVG SPD 0.11 KTS DEPTH = 0.1 M						
N	55	1243	47-15-54	122-23-23		
					0.11	328
N	101	1359	47-16- 1	122-23-30		
DROGUE = 59. MOVED 0.21 NMI IN 1.43 HRS. AVG SPD 0.15 KTS DEPTH = 0.5 M						
N	2	1119	47-15-41	122-23- 5		
					0.13	330
N	28	1157	47-15-46	122-23- 9		
					0.16	326
N	56	1245	47-15-52	122-23-15		
DROGUE = 59. MOVED 0.23 NMI IN 1.19 HRS. AVG SPD 0.19 KTS DEPTH = 0.5 M						
N	57	1246	47-15-50	122-23-18		
					0.19	324
N	100	1358	47-16- 2	122-23-30		
DROGUE = 65. MOVED 0.07 NMI IN 2.81 HRS. AVG SPD 0.02 KTS DEPTH = 1.0 M						
N	3	1119	47-15-41	122-23- 5		
					0.01	214
N	32	1201	47-15-41	122-23- 6		
					0.02	120
N	62	1252	47-15-40	122-23- 4		
					0.05	87
N	105	1408	47-15-40	122-22-58		
DROGUE = 71. MOVED 0.08 NMI IN 2.76 HRS. AVG SPD 0.03 KTS DEPTH = 2.0 M						
N	4	1119	47-15-41	122-23- 5		
					0.05	328
N	30	1159	47-15-43	122-23- 7		
					0.06	308
N	59	1248	47-15-45	122-23-11		
					0.02	59
N	103	1405	47-15-46	122-23- 8		
DROGUE = 83. MOVED 0.10 NMI IN 2.75 HRS. AVG SPD 0.03 KTS DEPTH = 3.0 M						
N	5	1119	47-15-41	122-23- 5		
					0.08	320
N	29	1158	47-15-44	122-23- 8		
					0.05	348
N	58	1247	47-15-47	122-23- 9		
					0.00	17
N	102	1404	47-15-47	122-23- 9		

TABLE 2.16-I (continued)

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 INNER SET 1

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 94. MOVED 0.07 NMI IN 1.50 HRS. AVG SPD 0.04 KTS DEPTH - 4.0 M						
N	6	1119	47-15-41	122-23- 5		
					0.07	353
N	34	1203	47-15-45	122-23- 6		
					0.02	359
N	60	1249	47-15-46	122-23- 6		
DROGUE - 94. MOVED 0.02 NMI IN 1.26 HRS. AVG SPD 0.01 KTS DEPTH - 4.0 M						
N	61	1250	47-15-44	122-23- 8		
					0.01	15
N	104	1406	47-15-46	122-23- 7		
DROGUE - 104. MOVED 0.03 NMI IN 2.86 HRS. AVG SPD 0.01 KTS DEPTH - 6.0 M						
N	7	1119	47-15-41	122-23- 5		
					0.02	217
N	31	1200	47-15-41	122-23- 6		
					0.01	143
N	63	1252	47-15-40	122-23- 5		
					0.01	103
N	107	1411	47-15-40	122-23- 4		
DROGUE - 112. MOVED 0.04 NMI IN 2.85 HRS. AVG SPD 0.01 KTS DEPTH - 10.0 M						
N	8	1119	47-15-41	122-23- 5		
					0.01	90
N	33	1202	47-15-41	122-23- 4		
					0.02	108
N	64	1253	47-15-41	122-23- 2		
					0.01	27
N	106	1410	47-15-42	122-23- 2		

TABLE 2.17-0

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 OUTER SET 2

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 21. MOVED 0.14 NMI IN 0.66 HRS. AVG SPD 0.21 KTS DEPTH - 0.1 M						
N	89	1345	47-16-29	122-24-24		
					0.21	328
N	122	1425	47-16-36	122-24-31		
DROGUE - 57. MOVED 0.31 NMI IN 1.76 HRS. AVG SPD 0.17 KTS DEPTH - 0.5 M						
N	90	1345	47-16-29	122-24-24		
					0.17	321
N	121	1424	47-16-34	122-24-31		
					0.17	328
N	149	1531	47-16-45	122-24-40		
DROGUE - 64. MOVED 0.27 NMI IN 1.79 HRS. AVG SPD 0.15 KTS DEPTH - 1.0 M						
N	91	1345	47-16-29	122-24-24		
					0.10	299
N	120	1422	47-16-31	122-24-29		
					0.17	313
N	150	1533	47-16-40	122-24-43		
DROGUE - 73. MOVED 0.11 NMI IN 1.71 HRS. AVG SPD 0.06 KTS DEPTH - 2.0 M						
N	92	1345	47-16-29	122-24-24		
					0.07	325
N	117	1420	47-16-31	122-24-26		
					0.06	352
N	148	1528	47-16-36	122-24-27		
DROGUE - 87. MOVED 0.11 NMI IN 1.69 HRS. AVG SPD 0.06 KTS DEPTH - 3.0 M						
N	93	1345	47-16-29	122-24-24		
					0.06	336
N	118	1421	47-16-31	122-24-25		
					0.07	337
N	147	1527	47-16-36	122-24-28		
DROGUE - 92. MOVED 0.00 NMI IN 0.00 HRS. AVG SPD 0.00 KTS DEPTH - 4.0 M						
N	119	1421	47-16-30	122-24-25		
					0.01	339
N	118	1421	47-16-31	122-24-25		
DROGUE - 92. MOVED 0.09 NMI IN 1.68 HRS. AVG SPD 0.05 KTS DEPTH - 4.0 M						
N	94	1345	47-16-29	122-24-24		
					0.05	337
N	146	1526	47-16-34	122-24-27		
DROGUE - 100. MOVED 0.05 NMI IN 1.66 HRS. AVG SPD 0.03 KTS DEPTH - 6.0 M						
N	95	1345	47-16-29	122-24-24		
					0.02	101
N	116	1420	47-16-29	122-24-23		
					0.04	18
N	145	1525	47-16-32	122-24-21		

TABLE 2.17-0 (continued)

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 OUTER SET 2

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 111. MOVED 0.18 NMI IN 1.94 HRS. AVG SPD 0.09 KTS						
DEPTH - 10.0 M						
N	96	1345	47-16-29	122-24-24		
					0.14	133
N	123	1430	47-16-25	122-24-17		
					0.06	113
N	151	1542	47-16-23	122-24-11		

TABLE 2.17-M

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 MIDDLE SET 2

DROGUE - 27. MOVED 0.13 NMI IN 0.41 HRS. AVG SPD 0.32 KTS
DEPTH - 0.1 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	73	1325	47-16- 5	122-23-45		
					0.32	331
N	97	1350	47-16-12	122-23-51		

DROGUE - 8. MOVED 0.37 IN 1.94 HRS. AVG SPD 0.19 KTS
DEPTH - 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	74	1325	47-16- 5	122-23-45		
					0.25	330
N	98	1351	47-16-11	122-23-50		
					0.17	321
N	144	1522	47-16-23	122-24- 5		

DROGUE - 67. MOVED 0.24 NMI IN 1.89 HRS. AVG SPD 0.13 KTS
DEPTH - 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	75	1325	47-16- 5	122-23-45		
					0.16	307
N	99	1352	47-16- 7	122-23-50		
					0.11	308
N	124	1436	47-16-11	122-23-56		
					0.12	320
N	143	1519	47-16-15	122-24- 1		

DROGUE - 72. MOVED 0.06 NMI IN 1.58 HRS. AVG SPD 0.04 KTS
DEPTH - 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	76	1325	47-16- 5	122-23-45		
					0.03	53
N	128	1439	47-16- 7	122-23-42		
					0.08	116
N	138	1500	47-16- 6	122-23-39		

DROGUE - 81. MOVED 0.13 NMI IN 1.85 HRS. AVG SPD 0.07 KTS
DEPTH - 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	77	1325	47-16- 5	122-23-45		
					0.05	325
N	125	1437	47-16- 8	122-23-48		
					0.11	311
N	142	1516	47-16-11	122-23-53		

DROGUE - 93. MOVED 0.07 NMI IN 1.61 HRS. AVG SPD 0.04 KTS
DEPTH - 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	78	1325	47-16- 5	122-23-45		
					0.03	32
N	127	1439	47-16- 7	122-23-43		
					0.12	322
N	140	1502	47-16- 9	122-23-46		

DROGUE - 102. MOVED 0.06 NMI IN 1.58 HRS. AVG SPD 0.04 KTS
DEPTH - 6.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	79	1325	47-16- 5	122-23-45		
					0.04	65
N	129	1440	47-16- 6	122-23-41		
					0.06	116
N	139	1500	47-16- 6	122-23-39		

TABL 2.17-M (continued)

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 MIDDLE SET 2

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 113. MOVED 0.05 NMI IN 1.64 HRS. AVG SPD 0.03 KTS						
DEPTH - 10.0 M						
N	80	1325	47-16- 5	122-23-45		
					0.02	359
N	126	1438	47-16- 7	122-23-45		
					0.05	23
N	141	1504	47-16- 8	122-23-44		

TABLE 2.17-I

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 INNER SET 2

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE = 28. MOVED 0.42 NMI IN 1.00 HRS. AVG SPD 0.42 KTS DEPTH = 0.1 M						
N	137	1451	47-15-41	122-23- 6		
					0.42	320
N	152	1551	47-16- 1	122-23-30		
DROGUE = 59. MOVED 0.33 NMI IN 1.01 HRS. AVG SPD 0.33 KTS DEPTH = 0.5 M						
N	136	1451	47-15-41	122-23- 6		
					0.33	323
N	153	1552	47-15-58	122-23-24		
DROGUE = 65. MOVED 0.04 NMI IN 1.80 HRS. AVG SPD 0.02 KTS DEPTH = 1.0 M						
N	110	1412	47-15-41	122-23- 4		
					0.04	118
N	130	1446	47-15-41	122-23- 2		
					0.01	99
N	158	1600	47-15-41	122-23- 0		
DROGUE = 71. MOVED 0.03 NMI IN 0.58 HRS. AVG SPD 0.05 KTS DEPTH = 2.0 M						
N	111	1412	47-15-41	122-23- 4		
					0.05	35
N	131	1447	47-15-43	122-23- 2		
DROGUE = 83. MOVED 0.07 NMI IN 1.73 HRS. AVG SPD 0.04 KTS DEPTH = 3.0 M						
N	112	1412	47-15-41	122-23- 4		
					0.07	343
N	135	1449	47-15-44	122-23- 5		
					0.02	323
N	154	1556	47-15-45	122-23- 7		
DROGUE = 94. MOVED 0.03 NMI IN 1.76 HRS. AVG SPD 0.02 KTS DEPTH = 4.0 M						
N	113	1412	47-15-41	122-23- 4		
					0.02	11
N	133	1448	47-15-42	122-23- 4		
					0.02	302
N	156	1558	47-15-43	122-23- 6		
DROGUE = 104. MOVED 0.04 NMI IN 1.78 HRS. AVG SPD 0.02 KTS DEPTH = 6.0 M						
N	114	1412	47-15-41	122-23- 4		
					0.02	322
N	134	1448	47-15-42	122-23- 5		
					0.03	260
N	157	1559	47-15-42	122-23- 8		
DROGUE = 112. MOVED 0.05 NMI IN 1.75 HRS. AVG SPD 0.03 KTS DEPTH = 10.0 M						
N	115	1412	47-15-41	122-23- 4		
					0.04	15
N	132	1447	47-15-43	122-23- 3		
					0.02	330
N	155	1557	47-15-45	122-23- 5		

C

TABLE 2.18-0

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 OUTER SET 3

DROGUE - 32. MOVED 0.09 NMI IN 1.01 HRS. AVG SPD 0.09 KTS
DEPTH - 0.1 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	159	1750	47-16-28	122-24-20		
					0.06	110
N	185	1830	47-16-27	122-24-16		
					0.14	119
N	196	1851	47-16-25	122-24-12		

DROGUE - 8. MOVED 0.06 NMI IN 1.00 HRS. AVG SPD 0.06 KTS
DEPTH - 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	160	1750	47-16-28	122-24-20		
					0.04	101
N	186	1831	47-16-27	122-24-17		
					0.11	127
N	195	1850	47-16-26	122-24-15		

DROGUE - 67. MOVED 0.08 NMI IN 0.83 HRS. AVG SPD 0.09 KTS
DEPTH - 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	161	1750	47-16-28	122-24-20		
					0.09	336
N	190	1840	47-16-32	122-24-23		

DROGUE - 72. MOVED 0.12 NMI IN 0.81 HRS. AVG SPD 0.14 KTS
DEPTH - 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	162	1750	47-16-28	122-24-20		
					0.14	334
N	189	1839	47-16-35	122-24-25		

DROGUE - 81. MOVED 0.03 NMI IN 0.96 HRS. AVG SPD 0.03 KTS
DEPTH - 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	163	1750	47-16-28	122-24-20		
					0.03	139
N	187	1832	47-16-27	122-24-19		
					0.02	117
N	194	1848	47-16-27	122-24-18		

DROGUE - 93. MOVED 0.08 NMI IN 0.93 HRS. AVG SPD 0.09 KTS
DEPTH - 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	164	1750	47-16-28	122-24-20		
					0.10	270
N	188	1834	47-16-28	122-24-27		
					0.07	296
N	193	1846	47-16-28	122-24-28		

DROGUE - 102. MOVED 0.15 NMI IN 0.86 HRS. AVG SPD 0.18 KTS
DEPTH - 6.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	165	1750	47-16-28	122-24-20		
					0.18	290
N	191	1842	47-16-31	122-24-33		

DROGUE - 113. MOVED 0.05 NMI IN 0.91 HRS. AVG SPD 0.06 KTS
DEPTH - 10.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	166	1750	47-16-28	122-24-20		
					0.06	314
N	192	1845	47-16-30	122-24-24		

TABLE 2.18-M

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 MIDDLE SET 3

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 28. MOVED 0.26 NMI IN 0.88 HRS. AVG SPD 0.29 KTS DEPTH - 0.1 M						
N	167	1801	47-16- 3	122-23-43		
					0.31	293
N	184	1825	47-16- 6	122-23-54		
					0.29	314
N	197	1854	47-16-12	122-24- 3		
DROGUE - 59. MOVED 0.22 NMI IN 0.91 HRS. AVG SPD 0.24 KTS DEPTH - 0.5 M						
N	168	1801	47-16- 3	122-23-43		
					0.22	298
N	183	1824	47-16- 6	122-23-50		
					0.25	305
N	198	1856	47-16-11	122-24- 0		
DROGUE - 64. MOVED 0.08 NMI IN 0.98 HRS. AVG SPD 0.08 KTS DEPTH - 1.0 M						
N	169	1801	47-16- 3	122-23-43		
					0.08	289
N	201	1900	47-16- 5	122-23-50		
DROGUE - 71. MOVED 0.07 NMI IN 1.11 HRS. AVG SPD 0.07 KTS DEPTH - 2.0 M						
N	170	1801	47-16- 3	122-23-43		
					0.07	121
N	204	1908	47-16- 1	122-23-37		
DROGUE - 87. MOVED 0.03 NMI IN 1.08 HRS. AVG SPD 0.03 KTS DEPTH - 3.0 M						
N	171	1801	47-16- 3	122-23-43		
					0.03	111
N	203	1906	47-16- 3	122-23-41		
DROGUE - 92. MOVED 0.10 NMI IN 0.96 HRS. AVG SPD 0.10 KTS DEPTH - 4.0 M						
N	172	1801	47-16- 3	122-23-43		
					0.10	295
N	200	1859	47-16- 6	122-23-52		
DROGUE - 100. MOVED 0.11 NMI IN 0.94 HRS. AVG SPD 0.11 KTS DEPTH - 6.0 M						
N	173	1801	47-16- 3	122-23-43		
					0.11	304
N	199	1858	47-16- 7	122-23-52		
DROGUE - 111. MOVED 0.07 NMI IN 1.03 HRS. AVG SPD 0.06 KTS DEPTH - 10.0 M						
N	174	1801	47-16- 3	122-23-43		
					0.06	285
N	202	1903	47-16- 4	122-23-49		

TABLE 2.18-I

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 INNER SET 3

DROGUE - 57. MOVED 0.25 NMI IN 1.00 HRS. AVG SPD 0.25 KTS
DEPTH - 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	176	1814	47-15-40	122-23- 0	0.25	302
N	205	1914	47-15-48	122-23-19		

DROGUE - 65. MOVED 0.09 NMI IN 1.08 HRS. AVG SPD 0.09 KTS
DEPTH - 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	177	1814	47-15-40	122-23- 0	0.09	290
N	206	1919	47-15-42	122-23- 8		

DROGUE - 73. MOVED 0.08 NMI IN 1.20 HRS. AVG SPD 0.07 KTS
DEPTH - 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	178	1814	47-15-40	122-23- 0	0.07	323
N	211	1926	47-15-44	122-23- 4		

DROGUE - 83. MOVED 0.06 NMI IN 1.15 HRS. AVG SPD 0.05 KTS
DEPTH - 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	179	1814	47-15-40	122-23- 0	0.05	264
N	209	1923	47-15-40	122-23- 5		

DROGUE - 94. MOVED 0.06 NMI IN 1.16 HRS. AVG SPD 0.05 KTS
DEPTH - 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	180	1814	47-15-40	122-23- 0	0.05	230
N	210	1924	47-15-38	122-23- 4		

DROGUE - 104. MOVED 0.07 NMI IN 1.13 HRS. AVG SPD 0.06 KTS
DEPTH - 6.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	181	1814	47-15-40	122-23- 0	0.06	284
N	208	1922	47-15-41	122-23- 6		

DROGUE - 112. MOVED 0.07 NMI IN 1.11 HRS. AVG SPD 0.07 KTS
DEPTH - 10.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	182	1814	47-15-40	122-23- 0	0.07	285
N	207	1921	47-15-41	122-23- 6		

TABLE 2.19-0

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 OUTER SET 4

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 28. MOVED 0.18 NMI IN 1.06 HRS. AVG SPD 0.17 KTS DEPTH - 0.1 M						
N	220	2028	47-16-28	122-24-23	0.17	325
N	254	2132	47-16-37	122-24-33		
DROGUE - 59. MOVED 0.09 NMI IN 0.90 HRS. AVG SPD 0.10 KTS DEPTH - 0.5 M						
N	221	2028	47-16-28	122-24-23	0.10	318
N	248	2122	47-16-32	122-24-29		
DROGUE - 65. MOVED 0.14 NMI IN 0.96 HRS. AVG SPD 0.15 KTS DEPTH - 1.0 M						
N	222	2028	47-16-20	122-24-23	0.15	299
N	250	2126	47-16-33	122-24-35		
DROGUE - 73. MOVED 0.15 NMI IN 0.98 HRS. AVG SPD 0.15 KTS DEPTH - 2.0 M						
N	223	2028	47-16-28	122-24-23	0.15	302
N	251	2127	47-16-33	122-24-35		
DROGUE - 83. MOVED 0.25 NMI IN 1.01 HRS. AVG SPD 0.25 KTS DEPTH - 3.0 M						
N	224	2028	47-16-28	122-24-23	0.25	310
N	252	2129	47-16-38	122-24-41		
DROGUE - 94. MOVED 0.27 NMI IN 1.03 HRS. AVG SPD 0.26 KTS DEPTH - 4.0 M						
N	225	2028	47-16-28	122-24-23	0.26	322
N	253	2130	47-16-41	122-24-38		
DROGUE - 104. MOVED 0.11 NMI IN 0.93 HRS. AVG SPD 0.12 KTS DEPTH - 6.0 M						
N	226	2028	47-16-28	122-24-23	0.12	305
N	249	2124	47-16-32	122-24-32		
DROGUE - 112. MOVED 0.05 NMI IN 0.86 HRS. AVG SPD 0.05 KTS DEPTH - 10.0 M						
N	227	2028	47-16-28	122-24-23	0.05	220
N	247	2120	47-16-26	122-24-26		

TABLE 2.19-M

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 MIDDLE SET 4

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 8. MOVED 0.34 NMI IN 1.45 HRS. AVG SPD 0.23 KTS DEPTH - 0.1 M						
N	212	2011	47-16- 3	122-23-46		
					0.24	316
N	229	2037	47-16- 8	122-23-53		
					0.27	320
N	246	2117	47-16-16	122-24- 3		
					0.17	332
N	255	2138	47-16-20	122-24- 5		
DROGUE - 32. MOVED 0.24 NMI IN 1.08 HRS. AVG SPD 0.22 KTS DEPTH - 0.5 M						
N	213	2011	47-16- 3	122-23-46		
					0.37	313
N	228	2036	47-16-10	122-23-56		
					0.13	306
N	245	2116	47-16-13	122-24- 3		
DROGUE - 67. MOVED 0.11 NMI IN 1.53 HRS. AVG SPD 0.07 KTS DEPTH - 1.0 M						
N	214	2011	47-16- 3	122-23-46		
					0.15	311
N	230	2039	47-16- 6	122-23-51		
					0.07	261
N	244	2114	47-16- 6	122-23-55		
					0.02	288
N	258	2143	47-16- 6	122-23-56		
DROGUE - 72. MOVED 0.06 NMI IN 1.61 HRS. AVG SPD 0.03 KTS DEPTH - 2.0 M						
N	215	2011	47-16- 3	122-23-46		
					0.05	347
N	235	2044	47-16- 5	122-23-47		
					0.02	334
N	261	2148	47-16- 7	122-23-48		
DROGUE - 81. MOVED 0.14 NMI IN 2.16 HRS. AVG SPD 0.06 KTS DEPTH - 3.0 M						
N	216	2011	47-16- 3	122-23-46		
					0.16	359
N	233	2042	47-16- 8	122-23-46		
					0.04	282
N	259	2146	47-16- 9	122-23-50		
					0.06	314
N	272	2221	47-16-11	122-23-53		
DROGUE - 93. MOVED 0.25 NMI IN 2.11 HRS. AVG SPD 0.11 KTS DEPTH - 4.0 M						
N	217	2011	47-16- 3	122-23-46		
					0.17	355
N	232	2042	47-16- 9	122-23-47		
					0.14	304
N	257	2141	47-16-14	122-23-57		
					0.06	332
N	271	2218	47-16-16	122-23-59		

TABLE 2.19-M (continued)

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 MIDDLE SET 4

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 102. MOVED 0.25 NMI IN 2.04 HRS. AVG SPD 0.12 KTS DEPTH - 6.0 M						
N	218	2011	47-16- 3	122-23-46		
					0.17	334
N	231	2041	47-16- 8	122-23-50		
					0.11	307
N	256	2140	47-16-12	122-23-58		
					0.09	331
N	270	2214	47-16-15	122-24- 0		
DROGUE - 113. MOVED 0.08 NMI IN 1.60 HRS. AVG SPD 0.05 KTS DEPTH - 10.0 M						
N	219	2011	47-16- 3	122-23-46		
					0.08	338
N	234	2043	47-16- 6	122-23-48		
					0.03	324
N	260	2147	47-16- 8	122-23-50		

TALBE 2.19-I

BLAIR WATERWAY WINTER STUDY 17 FEB 1981 INNER SET 4

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 40. MOVED 0.32 NMI IN 0.79 HRS. AVG SPD 0.40 KTS DEPTH - 0.1 M						
N	236	2104	47-15-41	122-23- 5	0.40	314
N	262	2152	47-15-55	122-23-26		
DROGUE - 57. MOVED 0.24 NMI IN 0.83 HRS. AVG SPD 0.29 KTS DEPTH - 0.5 M						
N	237	2104	47-15-41	122-23- 5	0.29	311
N	263	2154	47-15-51	122-23-21		
DROGUE - 64. MOVED 0.18 NMI IN 0.84 HRS. AVG SPD 0.21 KTS DEPTH - 1.0 M						
N	238	2104	47-15-41	122-23- 5	0.21	308
N	264	2155	47-15-48	122-23-18		
DROGUE - 71. MOVED 0.10 NMI IN 0.88 HRS. AVG SPD 0.12 KTS DEPTH - 2.0 M						
N	239	2104	47-15-41	122-23- 5	0.12	320
N	266	2157	47-15-46	122-23-11		
DROGUE - 87. MOVED 0.11 NMI IN 0.86 HRS. AVG SPD 0.12 KTS DEPTH - 3.0 M						
N	240	2104	47-15-41	122-23- 5	0.12	315
N	265	2156	47-15-46	122-23-12		
DROGUE - 92. MOVED 0.11 NMI IN 0.98 HRS. AVG SPD 0.11 KTS DEPTH - 4.0 M						
[illegible]	241	2104	47-15-41	122-23- 5	0.11	300
N	269	2203	47-15-45	122-23-14		
DROGUE - 100. MOVED 0.05 NMI IN 0.91 HRS. AVG SPD 0.05 KTS DEPTH - 6.0 M						
N	242	2104	47-15-41	122-23- 5	0.05	329
N	267	2159	47-15-44	122-23- 7		
DROGUE - 111. MOVED 0.01 NMI IN 0.93 HRS. AVG SPD 0.01 KTS DEPTH - 10.0 M						
N	243	2104	47-15-41	122-23- 5	0.01	90
N	268	2200	47-15-41	122-23- 4		

TALBE 2.20-0

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 OUTER SET 5

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 40. MOVED 0.31 NMI IN 0.63 HRS. AVG SPD 0.50 KTS DEPTH - 0.1 M						
N	281	5	47-16-30	122-24-26		
					0.50	131
N	308	43	47-16-18	122-24- 4		
DROGUE - 40. MOVED 0.09 NMI IN 1.43 HRS. AVG SPD 0.06 KTS DEPTH - 0.1 M						
N	315	53	47-16-30	122-24-24		
					0.06	80
N	344	219	47-16-31	122-24-16		
DROGUE - 57. MOVED 0.34 NMI IN 0.61 HRS. AVG SPD 0.55 KTS DEPTH - 0.5 M						
N	282	5	47-16-30	122-24-26		
					0.55	131
N	307	42	47-16-17	122-24- 3		
DROGUE - 57. MOVED 0.09 NMI IN 1.40 HRS. AVG SPD 0.06 KTS DEPTH - 0.5 M						
N	316	53	47-16-30	122-24-24		
					0.06	85
N	343	217	47-16-30	122-24-16		
DROGUE - 65. MOVED 0.32 NMI IN 2.03 HRS. AVG SPD 0.16 KTS DEPTH - 1.0 M						
N	283	5	47-16-30	122-24-26		
					0.20	119
N	310	47	47-16-26	122-24-15		
					0.14	120
N	340	207	47-16-20	122-24- 0		
DROGUE - 73. MOVED 0.25 NMI IN 2.08 HRS. AVG SPD 0.12 KTS DEPTH - 2.0 M						
N	284	5	47-16-30	122-24-26		
					0.12	122
N	312	49	47-16-27	122-24-19		
					0.12	117
N	341	210	47-16-23	122-24- 6		
DROGUE - 83. MOVED 0.06 NMI IN 0.76 HRS. AVG SPD 0.08 KTS DEPTH - 3.0 M						
N	285	5	47-16-30	122-24-26		
					0.08	154
N	314	51	47-16-27	122-24-23		
DROGUE - 94. MOVED 0.20 NMI IN 2.13 HRS. AVG SPD 0.09 KTS DEPTH - 4.0 M						
N	286	5	47-16-30	122-24-26		
					0.08	132
N	313	50	47-16-27	122-24-21		
					0.10	108
N	342	213	47-16-25	122-24-10		

TALBE 2.20-0 (continued)

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 OUTER SET 5

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 104. MOVED 0.34 NMI IN 1.99 HRS. AVG SPD 0.17 KTS DEPTH - 6.0 M						
N	287	5	47-16-30	122-24-26		
					0.17	117
N	311	48	47-16-27	122-24-16		
					0.17	127
N	339	205	47-16-19	122-24- 0		
DROGUE - 112. MOVED 0.53 NMI IN 1.88 HRS. AVG SPD 0.28 KTS DEPTH - 10.0 M						
N	288	5	47-16-30	122-24-26		
					0.23	134
N	309	45	47-16-24	122-24-16		
					0.30	131
N	338	158	47-16- 9	122-23-51		

TALBE 2.20-M

BLAIR WATERWAY WINTER STUDY 17-18 FEB 1981 MIDDLE SET 5

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR

DROGUE = 21. MOVED 0.27 NMI IN 0.61 HRS. AVG SPD 0.44 KTS
DEPTH = 0.1 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	273	2355	47-16- 9	122-23-48		
					0.50	149
N	290	17	47-15-59	122-23-40		
					0.38	117
N	299	32	47-15-57	122-23-32		

DROGUE = 8. MOVED 0.22 NMI IN 0.63 HRS. AVG SPD 0.36 KTS
DEPTH = 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	274	2355	47-16- 7	122-23-48		
					0.33	145
N	289	16	47-16- 1	122-23-42		
					0.40	125
N	300	33	47-15-57	122-23-34		

DROGUE = 64. MOVED 0.30 NMI IN 1.40 HRS. AVG SPD 0.22 KTS
DEPTH = 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	275	2355	47-16- 7	122-23-48		
					0.18	139
N	301	34	47-16- 2	122-23-41		
					0.25	124
N	317	119	47-15-55	122-23-27		

DROGUE = 71. MOVED 0.13 NMI IN 2.81 HRS. AVG SPD 0.04 KTS
DEPTH = 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	276	2355	47-16- 7	122-23-48		
					0.01	161
N	306	40	47-16- 7	122-23-48		
					0.08	150
N	336	154	47-16- 1	122-23-43		
					0.07	64
N	354	244	47-16- 3	122-23-39		

DROGUE = 87. MOVED 0.09 NMI IN 2.80 HRS. AVG SPD 0.03 KTS
DEPTH = 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	277	2355	47-16- 7	122-23-48		
					0.09	150
N	303	38	47-16- 4	122-23-45		
					0.03	148
N	335	154	47-16- 1	122-23-43		
					0.03	10
N	353	243	47-16- 3	122-23-42		

DROGUE = 92. MOVED 0.06 NMI IN 2.76 HRS. AVG SPD 0.02 KTS
DEPTH = 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	278	2355	47-16- 7	122-23-48		
					0.08	128
N	305	39	47-16- 5	122-23-44		
					0.02	70
N	337	155	47-16- 6	122-23-41		
					0.07	339
N	352	241	47-16- 9	122-23-42		

TALBE 2.20-M (continued)

BLAIR WATERWAY WINTER STUDY 17-18 FEB 1981 MIDDLE SET 5

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 100. MOVED 0.25 NMI IN 2.85 HRS. AVG SPD 0.08 KTS DEPTH - 6.0 M						
N	279	2355	47-16- 7	122-23-48		
					0.09	140
N	304	38	47-16- 4	122-23-44		
					0.11	118
N	334	150	47-16- 0	122-23-34		
					0.05	100
N	355	246	47-15-59	122-23-29		
DROGUE - 111. MOVED 0.26 NMI IN 1.90 HRS. AVG SPD 0.14 KTS DEPTH - 10.0 M						
N	280	2355	47-16- 7	122-23-48		
					0.15	141
N	302	36	47-16- 2	122-23-42		
					0.13	123
N	332	149	47-15-57	122-23-30		

TABLE 2.20-I

BLAIR WATERWAY WINTER STUDY - 18 FEB 1981 INNER SET 5

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 28. MOVED 0.03 NMI IN 1.01 HRS. AVG SPD 0.03 KTS DEPTH - 0.1 M						
N	291	25	47-15-42	122-23- 6	0.03	34
N	320	126	47-15-43	122-23- 4		
DROGUE - 59. MOVED 0.42 NMI IN 1.16 HRS. AVG SPD 0.36 KTS DEPTH - 0.5 M						
N	292	25	47-15-42	122-23- 6	0.36	18
N	326	135	47-16- 6	122-22-54		
DROGUE - 59. MOVED 0.48 NMI IN 1.61 HRS. AVG SPD 0.29 KTS DEPTH - 0.5 M						
N	327	136	47-16- 8	122-22-59	0.29	158
N	362	313	47-15-41	122-22-43		
DROGUE - 8. MOVED 0.26 NMI IN 1.20 HRS. AVG SPD 0.22 KTS DEPTH - 0.5 M						
N	300	33	47-15-58	122-23-34	0.22	115
N	330	145	47-15-51	122-23-12		
DROGUE - 67. MOVED 0.10 NMI IN 1.10 HRS. AVG SPD 0.09 KTS DEPTH - 1.0 M						
N	293	25	47-15-42	122-23- 6	0.09	103
N	324	131	47-15-40	122-22-57		
DROGUE - 67. MOVED 0.54 NMI IN 1.68 HRS. AVG SPD 0.32 KTS DEPTH - 1.0 M						
N	325	133	47-16- 8	122-22-59	0.32	159
N	364	314	47-15-37	122-22-42		
DROGUE - 64. MOVED 0.37 NMI IN 1.70 HRS. AVG SPD 0.22 KTS DEPTH - 1.0 M						
N	318	119	47-15-56	122-23-27	0.28	132
N	331	147	47-15-50	122-23-18	0.19	125
N	358	301	47-15-42	122-23- 0		
DROGUE - 72. MOVED 0.26 NMI IN 2.79 HRS. AVG SPD 0.09 KTS DEPTH - 2.0 M						
N	294	25	47-15-42	122-23- 6	0.09	93
N	363	313	47-15-41	122-22-43		

TALBE 2.20-I (continued)

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 INNER SET 5

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 81. MOVED 0.06 NMI IN 2.61 HRS. AVG SPD 0.02 KTS DEPTH - 4.0 M						
N	295	25	47-15-42	122-23- 6		
					0.02	72
N	322	128	47-15-42	122-23- 3		
					0.02	90
N	359	302	47-15-42	122-23- 0		
DROGUE - 93. MOVED 0.05 NMI IN 1.25 HRS. AVG SPD 0.04 KTS DEPTH - 4.0 M						
N	296	25	47-15-42	122-23- 6		
					0.05	359
N	319	124	47-15-45	122-23- 6		
					0.02	359
N	328	140	47-15-45	122-23- 6		
DROGUE - 93. MOVED 0.01 NMI IN 1.21 HRS. AVG SPD 0.01 KTS DEPTH - 4.0 M						
N	329	142	47-15-44	122-23- 9		
					0.01	80
N	357	255	47-15-44	122-23- 7		
DROGUE - 102. MOVED 0.04 NMI IN 2.63 HRS. AVG SPD 0.01 KTS DEPTH - 6.0 M						
N	297	25	47-15-42	122-23- 6		
					0.02	41
N	321	126	47-15-43	122-23- 4		
					0.01	32
N	360	303	47-15-44	122-23- 3		
DROGUE - 113. MOVED 0.48 NMI IN 2.69 HRS. AVG SPD 0.17 KTS DEPTH - 10.0 M						
N	298	25	47-15-42	122-23- 6		
					0.07	113
N	323	130	47-15-40	122-23- 0		
					0.30	6
N	361	307	47-16-10	122-22-54		
DROGUE - 111. MOVED 0.12 NMI IN 1.01 HRS. AVG SPD 0.12 KTS DEPTH - 10.0 M						
N	333	149	47-15-57	122-23-30		
					0.12	110
N	356	250	47-15-55	122-23-19		

TALBE 2.21-0

BLAIR WATERWAY WINTER STUDY -18 FEB 1981 OUTER SET 6

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 65. MOVED 0.16 NMI IN 1.01 HRS. AVG SPD 0.15 KTS DEPTH - 1.0 M						
N	346	230	47-16-33	122-24-31	0.15	131
N	366	331	47-16-27	122-24-21		
DROGUE - 73. MOVED 0.25 NMI IN 1.04 HRS. AVG SPD 0.24 KTS DEPTH - 2.0 M						
N	347	230	47-16-33	122-24-31	0.24	134
N	367	333	47-16-23	122-24-15		
DROGUE - 83. MOVED 0.18 NMI IN 0.96 HRS. AVG SPD 0.19 KTS DEPTH - 3.0 M						
N	348	230	47-16-33	122-24-31	0.19	118
N	365	328	47-16-28	122-24-17		
DROGUE - 94. MOVED 0.13 NMI IN 1.10 HRS. AVG SPD 0.12 KTS DEPTH - 4.0 M						
N	349	230	47-16-33	122-24-31	0.12	151
N	368	336	47-16-26	122-24-26		
DROGUE - 104. MOVED 0.05 NMI IN 1.04 HRS. AVG SPD 0.05 KTS DEPTH - 6.0 M						
N	350	234	47-16-33	122-24-31	0.05	161
N	369	337	47-16-30	122-24-30		
DROGUE - 112. MOVED 0.05 NMI IN 1.06 HRS. AVG SPD 0.05 KTS DEPTH - 10.0 M						
N	351	234	47-16-33	122-24-31	0.05	203
N	370	338	47-16-30	122-24-33		

TALBE 2.21-M

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 MIDDLE SET 6

DROGUE = 59. MOVED 0.08 NMI IN 1.04 HRS. AVG SPD 0.08 KTS
DEPTH = 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	371	345	47-16- 7	122-23-49	0.08	81
N	380	448	47-16- 8	122-23-42		

DROGUE = 65. MOVED 0.08 NMI IN 0.98 HRS. AVG SPD 0.09 KTS
DEPTH = 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	372	345	47-16- 7	122-23-49	0.09	90
N	378	444	47-16- 7	122-23-41		

DROGUE = 73. MOVED 0.07 NMI IN 1.01 HRS. AVG SPD 0.07 KTS
DEPTH = 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	373	345	47-16- 7	122-23-49	0.07	69
N	379	446	47-16- 9	122-23-43		

DROGUE = 83. MOVED 0.03 NMI IN 1.14 HRS. AVG SPD 0.03 KTS
DEPTH = 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	374	345	47-16- 7	122-23-49	0.03	350
N	383	454	47-16-10	122-23-50		

DROGUE = 94. MOVED 0.08 NMI IN 1.[illegible]6 HRS. AVG SPD 0.07 KTS
DEPTH = 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	375	345	47-16- 7	122-23-49	0.07	351
N	384	455	47-16-12	122-23-50		

DROGUE = 104. MOVED 0.03 NMI IN 1.09 HRS. AVG SPD 0.02 KTS
DEPTH = 6.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	376	345	47-16- 7	122-23-49	0.02	36
N	381	451	47-16- 9	122-23-48		

DROGUE = 112. MOVED 0.01 NMI IN 1.11 HRS. AVG SPD 0.01 KTS
DEPTH = 10.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	377	345	47-16- 7	122-23-49	0.01	232
N	382	452	47-16- 7	122-23-50		

TABLE 2.22-0

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 OUTER SET 7

DROGUE - 40. MOVED 0.12 NMI IN 0.61 HRS. AVG SPD 0.20 KTS
DEPTH - 0.1 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	385	635	47-16-30	122-24-26		
					0.20	287
N	416	712	47-16-32	122-24-36		

DROGUE - 40. MOVED 0.32 NMI IN 1.78 HRS. AVG SPD 0.18 KTS
DEPTH - 0.1 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	417	714	47-16-31	122-24-25		
					0.12	337
N	438	754	47-16-35	122-24-28		
					0.21	320
N	484	901	47-16-46	122-24-41		

DROGUE - 59. MOVED 0.22 NMI IN 1.38 HRS. AVG SPD 0.15 KTS
DEPTH - 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	386	635	47-16-30	122-24-26		
					0.12	308
N	414	711	47-16-33	122-24-31		
					0.19	330
N	442	758	47-16-41	122-24-37		

DROGUE - 67. MOVED 0.21 NMI IN 1.36 HRS. AVG SPD 0.15 KTS
DEPTH - 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	387	635	47-16-30	122-24-26		
					0.04	332
N	413	710	47-16-32	122-24-27		
					0.23	324
N	441	757	47-16-41	122-24-37		

DROGUE - 72. MOVED 0.32 NMI IN 1.39 HRS. AVG SPD 0.23 KTS
DEPTH - 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	388	635	47-16-30	122-24-26		
					0.14	314
N	415	711	47-16-34	122-24-31		
					0.29	321
N	443	759	47-16-45	122-24-44		

DROGUE - 83. MOVED 0.51 NMI IN 2.46 HRS. AVG SPD 0.20 KTS
DEPTH - 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	389	635	47-16-30	122-24-26		
					0.06	304
N	412	709	47-16-31	122-24-29		
					0.09	327
N	440	756	47-16-35	122-24-32		
					0.36	319
N	485	903	47-16-54	122-24-56		

DROGUE - 94. MOVED 0.31 NMI IN 2.39 HRS. AVG SPD 0.13 KTS
DEPTH - 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	390	635	47-16-30	122-24-26		
					0.08	276
N	411	709	47-16-31	122-24-30		
					0.10	4
N	439	755	47-16-35	122-24-29		
					0.20	318
N	483	859	47-16-45	122-24-42		

TALBE 2.22-0 (continued)

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 OUTER SET 7

DROGUE = 102. MOVED 0.05 NMI IN 2.30 HRS. AVG SPD 0.02 KTS
DEPTH = 6.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	391	635	47-16-30	122-24-26		
					0.05	134
N	409	707	47-16-29	122-24-24		
					0.04	41
N	436	751	47-16-31	122-24-22		
					0.07	309
N	481	853	47-16-33	122-24-27		

DROGUE = 112. MOVED 0.08 NMI IN 2.33 HRS. AVG SPD 0.03 KTS
DEPTH = 10.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	392	635	47-16-30	122-24-26		
					0.01	90
N	410	708	47-16-30	122-24-25		
					0.02	23
N	437	752	47-16-31	122-24-24		
					0.07	322
N	482	855	47-16-35	122-24-28		

TALBE 2.22-M

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 MIDDLE SET 7

DROGUE - 28. MOVED 0.29 NMI IN 1.03 HRS. AVG SPD 0.28 KTS
DEPTH - 0.1 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	393	645	47-16- 4	122-23-44		
					0.27	293
N	418	717	47-16- 7	122-23-56		
					0.31	325
N	435	747	47-16-15	122-24- 4		

DROGUE - 57. MOVED 0.26 NMI IN 1.31 HRS. AVG SPD 0.20 KTS
DEPTH - 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	394	645	47-16- 4	122-23-44		
					0.17	281
N	419	718	47-16- 5	122-23-52		
					0.25	337
N	444	804	47-16-16	122-23-59		

DROGUE - 65. MOVED 0.10 NMI IN 1.79 HRS. AVG SPD 0.05 KTS
DEPTH - 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	395	645	47-16- 4	122-23-44		
					0.01	287
N	422	721	47-16- 4	122-23-45		
					0.07	337
N	447	807	47-16- 7	122-23-47		
					0.09	315
N	469	833	47-16- 9	122-23-49		

DROGUE - 73. MOVED 0.15 NMI IN 1.75 HRS. AVG SPD 0.08 KTS
DEPTH - 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	396	645	47-16- 4	122-23-44		
					0.07	287
N	421	720	47-16- 5	122-23-48		
					0.07	333
N	446	806	47-16- 8	122-23-50		
					0.15	293
N	467	830	47-16- 9	122-23-55		

DROGUE - 87. MOVED 0.15 NMI IN 1.76 HRS. AVG SPD 0.09 KTS
DEPTH - 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	397	645	47-16- 4	122-23-44		
					0.09	283
N	420	719	47-16- 5	122-23-49		
					0.08	339
N	445	805	47-16- 8	122-23-51		
					0.12	293
N	468	831	47-16-10	122-23-55		

DROGUE - 93. MOVED 0.07 NMI IN 1.89 HRS. AVG SPD 0.04 KTS
DEPTH - 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	398	645	47-16- 4	122-23-44		
					0.01	334
N	423	721	47-16- 4	122-23-44		
					0.07	258
N	449	809	47-16- 3	122-23-50		
					0.02	255
N	471	839	47-16- 3	122-23-51		

TABLE 2.22-M (continued)

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 MIDDLE SET 7

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 104. MOVED 0.08 NMI IN 1.88 HRS. AVG SPD 0.04 KTS DEPTH - 6.0 M						
N	399	645	47-16- 4	122-23-44		
					0.02	203
N	424	721	47-16- 3	122-23-44		
					0.06	284
N	448	808	47-16- 4	122-23-49		
					0.05	305
N	470	838	47-16- 5	122-23-51		
DROGUE - 111. MOVED 0.06 NMI IN 1.93 HRS. AVG SPD 0.03 KTS DEPTH - 10.0 M						
N	400	645	47-16- 4	122-23-44		
					0.08	225
N	425	722	47-16- 2	122-23-47		
					0.01	270
N	450	809	47-16- 2	122-23-48		
					0.01	270
N	472	841	47-16- 2	122-23-49		

TABLE 2.22-I

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 INNER SET 7

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 32. MOVED 0.43 NMI IN 1.28 HRS. AVG SPD 0.34 KTS DEPTH - 0.1 M						
N	401	655	47-15-41	122-23- 6		
					0.33	309
N	426	725	47-15-48	122-23-18		
					0.34	323
N	451	812	47-16- 1	122-23-32		
DROGUE - 8. MOVED 0.25 NMI IN 1.31 HRS. AVG SPD 0.19 KTS DEPTH - 0.5 M						
N	402	655	47-15-41	122-23- 6		
					0.14	317
N	427	726	47-15-45	122-23-11		
					0.22	315
N	452	814	47-15-52	122-23-22		
DROGUE - 64. MOVED 0.04 NMI IN 0.61 HRS. AVG SPD 0.06 KTS DEPTH - 1.0 M						
N	403	655	47-15-41	122-23- 6		
					0.06	256
N	433	732	47-15-41	122-23- 9		
DROGUE - 64. MOVED 0.10 NMI IN 0.76 HRS. AVG SPD 0.14 KTS DEPTH - 1.0 M						
N	434	733	47-15-42	122-23- 7		
					0.14	341
N	455	819	47-15-48	122-23-10		
DROGUE - 71. MOVED 0.12 NMI IN 1.41 HRS. AVG SPD 0.09 KTS DEPTH - 2.0 M						
N	404	655	47-15-41	122-23- 6		
					0.08	322
N	430	729	47-15-43	122-23- 9		
					0.09	341
N	456	820	47-15-48	122-23-11		
DROGUE - 81. MOVED 0.15 NMI IN 1.33 HRS. AVG SPD 0.11 KTS DEPTH - 3.0 M						
N	405	655	47-15-41	122-23- 6		
					0.12	314
N	428	728	47-15-44	122-23-10		
					0.10	306
N	453	815	47-15-47	122-23-16		
DROGUE - 92. MOVED 0.14 NMI IN 1.35 HRS. AVG SPD 0.10 KTS DEPTH - 4.0 M						
N	406	655	47-15-41	122-23- 6		
					0.09	304
N	429	729	47-15-43	122-23-10		
					0.11	308
N	454	816	47-15-46	122-23-16		
DROGUE - 100. MOVED 0.11 NMI IN 1.43 HRS. AVG SPD 0.08 KTS DEPTH - 6.0 M						
N	407	655	47-15-41	122-23- 6		
					0.07	307
N	431	730	47-15-43	122-23- 9		
					0.09	322
N	457	821	47-15-46	122-23-13		

TABLE 2.22-I (continued)

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 INNER SET 7

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 113. MOVED 0.02 NMI IN 1.44 HRS. AVG SPD 0.01 KTS						
DEPTH - 10.0 M						
N	408	655	47-15-41	122-23- 6		
					0.03	107
N	432	731	47-15-41	122-23- 4		
					0.00	66
N	458	822	47-15-41	122-23- 4		

TABLE 2.23-0

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 OUTER SET 8

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 40. MOVED 0.22 NMI IN 0.93 HRS. AVG SPD 0.23 KTS						
DEPTH - 0.1 M						
N	486	910	47-16-26	122-24-15		
					0.23	321
N	520	1006	47-16-36	122-24-28		
DROGUE - 27. MOVED 0.20 NMI IN 0.94 HRS. AVG SPD 0.21 KTS						
DEPTH - 0.5 M						
N	487	910	47-16-26	122-24-15		
					0.21	322
N	521	1007	47-16-35	122-24-26		
DROGUE - 67. MOVED 0.33 NMI IN 1.75 HRS. AVG SPD 0.19 KTS						
DEPTH - 1.0 M						
N	488	910	47-16-26	122-24-15		
					0.25	312
N	518	1004	47-16-35	122-24-30		
					0.13	332
N	539	1055	47-16-41	122-24-35		
DROGUE - 72. MOVED 0.48 NMI IN 1.71 HRS. AVG SPD 0.28 KTS						
DEPTH - 2.0 M						
N	489	910	47-16-26	122-24-15		
					0.27	311
N	519	1005	47-16-36	122-24-32		
					0.29	324
N	538	1053	47-16-47	122-24-44		
DROGUE - 83. MOVED 0.28 NMI IN 1.76 HRS. AVG SPD 0.16 KTS						
DEPTH - 3.0 M						
N	490	910	47-16-26	122-24-15		
					0.22	311
N	517	1003	47-16-34	122-24-29		
					0.10	336
N	540	1056	47-16-38	122-24-32		
DROGUE - 94. MOVED 0.20 NMI IN 1.66 HRS. AVG SPD 0.12 KTS						
DEPTH - 4.0 M						
N	491	910	47-16-26	122-24-15		
					0.14	308
N	516	1002	47-16-30	122-24-24		
					0.09	322
N	537	1050	47-16-34	122-24-28		
DROGUE - 102. MOVED 0.06 NMI IN 1.85 HRS. AVG SPD 0.03 KTS						
DEPTH - 6.0 M						
N	492	910	47-16-25	122-24-15		
					0.07	298
N	514	1000	47-16-27	122-24-20		
					0.01	57
N	542	1101	47-16-27	122-24-20		
DROGUE - 112. MOVED 0.18 NMI IN 1.79 HRS. AVG SPD 0.10 KTS						
DEPTH - 10.0 M						
N	493	910	47-16-26	122-24-15		
					0.13	310
N	515	1001	47-16-30	122-24-23		
					0.07	339
N	541	1058	47-16-34	122-24-26		

TABLE 2.23-M

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 MIDDLE SET 8

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 28. MOVED 0.33 NMI IN 1.18 HRS. AVG SPD 0.28 KTS DEPTH - 0.1 M						
N	473	844	47-16- 4	122-23-44		
					0.29	322
N	494	915	47-16-11	122-23-52		
					0.27	322
N	512	955	47-16-20	122-24- 2		
DROGUE - 59. MOVED 0.31 NMI IN 1.41 HRS. AVG SPD 0.21 KTS DEPTH - 0.5 M						
N	474	844	47-16- 4	122-23-44		
					0.25	319
N	495	916	47-16-10	122-23-52		
					0.19	323
N	522	1009	47-16-18	122-24- 1		
DROGUE - 65. MOVED 0.14 NMI IN 1.48 HRS. AVG SPD 0.10 KTS DEPTH - 1.0 M						
N	475	844	47-16- 4	122-23-44		
					0.10	310
N	499	920	47-16- 6	122-23-48		
					0.09	314
N	525	1013	47-16-10	122-23-53		
DROGUE - 73. MOVED 0.20 NMI IN 1.43 HRS. AVG SPD 0.14 KTS DEPTH - 2.0 M						
N	476	844	47-16- 4	122-23-44		
					0.20	327
N	496	917	47-16- 9	122-23-49		
					0.10	316
N	523	1010	47-16-13	122-23-55		
DROGUE - 87. MOVED 0.16 NMI IN 1.50 HRS. AVG SPD 0.10 KTS DEPTH - 3.0 M						
N	477	844	47-16- 4	122-23-44		
					0.12	287
N	498	919	47-16- 5	122-23-50		
					0.09	303
N	526	1014	47-16- 8	122-23-57		
DROGUE - 93. MOVED 0.16 NMI IN 1.46 HRS. AVG SPD 0.11 KTS DEPTH - 4.0 M						
N	478	844	47-16- 4	122-23-44		
					0.15	311
N	497	918	47-16- 7	122-23-49		
					0.08	308
N	524	1012	47-16-10	122-23-55		
DROGUE - 104. MOVED 0.11 NMI IN 1.51 HRS. AVG SPD 0.07 KTS DEPTH - 6.0 M						
N	479	844	47-16- 4	122-23-44		
					0.07	305
N	500	921	47-16- 5	122-23-47		
					0.07	311
N	527	1015	47-16- 8	122-23-51		

TABLE 2.23-M (continued)

BLAIR WATERWAY WINTER STUDY . 18 FEB 1981 MIDDLE SET 8

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE = 111. MOVED 0.10 NMI IN 1.53 HRS. AVG SPD 0.06 KTS						
DEPTH = 10.0 M						
N	480	844	47-16- 4	122-23-44		
					0.06	13
N	501	922	47-16- 6	122-23-43		
					0.08	334
N	528	1016	47-16-10	122-23-46		

TABLE 2.23-I

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 INNER SET 8

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 32. MOVED 0.27 NMI IN 1.30 HRS. AVG SPD 0.21 KTS DEPTH - 0.1 M						
N	459	822	47-15-41	122-23- 4	0.21	324
N	502	940	47-15-55	122-23-18		
DROGUE - 32. MOVED 0.08 NMI IN 0.56 HRS. AVG SPD 0.15 KTS DEPTH - 0.1 M						
N	510	950	47-15-41	122-23- 5	0.15	333
N	532	1024	47-15-46	122-23- 9		
DROGUE - 8. MOVED 0.16 NMI IN 1.35 HRS. AVG SPD 0.12 KTS DEPTH - 0.5 M						
N	460	822	47-15-41	122-23- 4	0.12	331
N	503	943	47-15-50	122-23-11		
DROGUE - 8. MOVED 0.10 NMI IN 0.55 HRS. AVG SPD 0.18 KTS DEPTH - 0.5 M						
N	511	950	47-15-41	122-23- 5	0.18	334
N	531	1023	47-15-47	122-23- 9		
DROGUE - 64. MOVED 0.06 NMI IN 2.08 HRS. AVG SPD 0.03 KTS DEPTH - 1.0 M						
N	461	822	47-15-41	122-23- 4	0.03	347
N	508	948	47-15-44	122-23- 5	0.03	319
N	535	1027	47-15-45	122-23- 6		
DROGUE - 71. MOVED 0.05 NMI IN 2.10 HRS. AVG SPD 0.02 KTS DEPTH - 2.0 M						
N	462	822	47-15-41	122-23- 4	0.03	316
N	507	947	47-15-43	122-23- 7	0.03	46
N	536	1028	47-15-44	122-23- 5		
DROGUE - 81. MOVED 0.12 NMI IN 2.00 HRS. AVG SPD 0.06 KTS DEPTH - 3.0 M						
N	463	822	47-15-41	122-23- 4	0.06	318
N	505	945	47-15-45	122-23- 9	0.05	334
N	530	1022	47-15-47	122-23-10		
DROGUE - 92. MOVED 0.10 NMI IN 2.06 HRS. AVG SPD 0.04 KTS DEPTH - 4.0 M						
N	464	822	47-15-41	122-23- 4	0.05	312
N	506	946	47-15-44	122-23- 9	0.02	290
N	534	1026	47-15-45	122-23-11		

TABLE 2.23-I (continued)

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 INNER SET 8

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 100. MOVED 0.20 NMI IN 1.96 HRS. AVG SPD 0.10 KTS DEPTH - 6.0 M						
N	465	822	47-15-41	122-23- 4		
					0.12	312
N	504	945	47-15-48	122-23-15		
					0.07	270
N	529	1020	47-15-48	122-23-18		
DROGUE - 113. MOVED 0.09 NMI IN 2.03 HRS. AVG SPD 0.04 KTS DEPTH - 10.0 M						
N	466	823	47-15-41	122-23- 4		
					0.04	342
N	509	948	47-15-45	122-23- 5		
					0.07	285
N	533	1025	47-15-45	122-23- 9		

TABLE 2.24-0

BLAIR WATERWAY WINTER STUDY 18 FEB 1981 OUTER SET 9

DROGUE - 40. MOVED 0.29 NMI IN 0.91 HRS. AVG SPD 0.31 KTS
DEPTH - 0.1 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	543	1155	47-16-28	122-24-22		
					0.27	135
N	559	1218	47-16-24	122-24-15		
					0.34	126
N	575	1250	47-16-17	122-24- 2		

DROGUE - 8. MOVED 0.22 NMI IN 0.93 HRS. AVG SPD 0.24 KTS
DEPTH - 0.5 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	544	1155	47-16-28	122-24-22		
					0.19	137
N	560	1219	47-16-25	122-24-17		
					0.28	119
N	576	1251	47-16-20	122-24- 6		

DROGUE - 64. MOVED 0.08 NMI IN 1.81 HRS. AVG SPD 0.04 KTS
DEPTH - 1.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	545	1115	47-16-28	122-24-22		
					0.05	73
N	561	1221	47-16-29	122-24-16		
					0.04	129
N	582	1304	47-16-28	122-24-14		

DROGUE - 72. MOVED 0.12 NMI IN 1.04 HRS. AVG SPD 0.11 KTS
DEPTH - 2.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	546	1155	47-16-28	122-24-22		
					0.05	308
N	565	1224	47-16-29	122-24-24		
					0.17	302
N	580	1258	47-16-32	122-24-31		

DROGUE - 83. MOVED 0.11 NMI IN 1.03 HRS. AVG SPD 0.10 KTS
DEPTH - 3.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	547	1155	47-16-28	122-24-22		
					0.07	302
N	566	1224	47-16-29	122-24-24		
					0.13	302
N	579	1257	47-16-32	122-24-30		

DROGUE - 94. MOVED 0.00 NMI IN 1.01 HRS. AVG SPD 0.00 KTS
DEPTH - 4.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	548	1155	47-16-28	122-24-22		
					0.02	72
N	564	1223	47-16-28	122-24-21		
					0.00	179
N	578	1256	47-16-28	122-24-21		

DROGUE - 102. MOVED 0.05 NMI IN 0.98 HRS. AVG SPD 0.05 KTS
DEPTH - 6.0 M

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
N	549	1155	47-16-28	122-24-22		
					0.06	116
N	562	1222	47-16-27	122-24-20		
					0.04	119
N	577	1254	47-16-27	122-24-18		

TABLE 2.24-0 (continued)

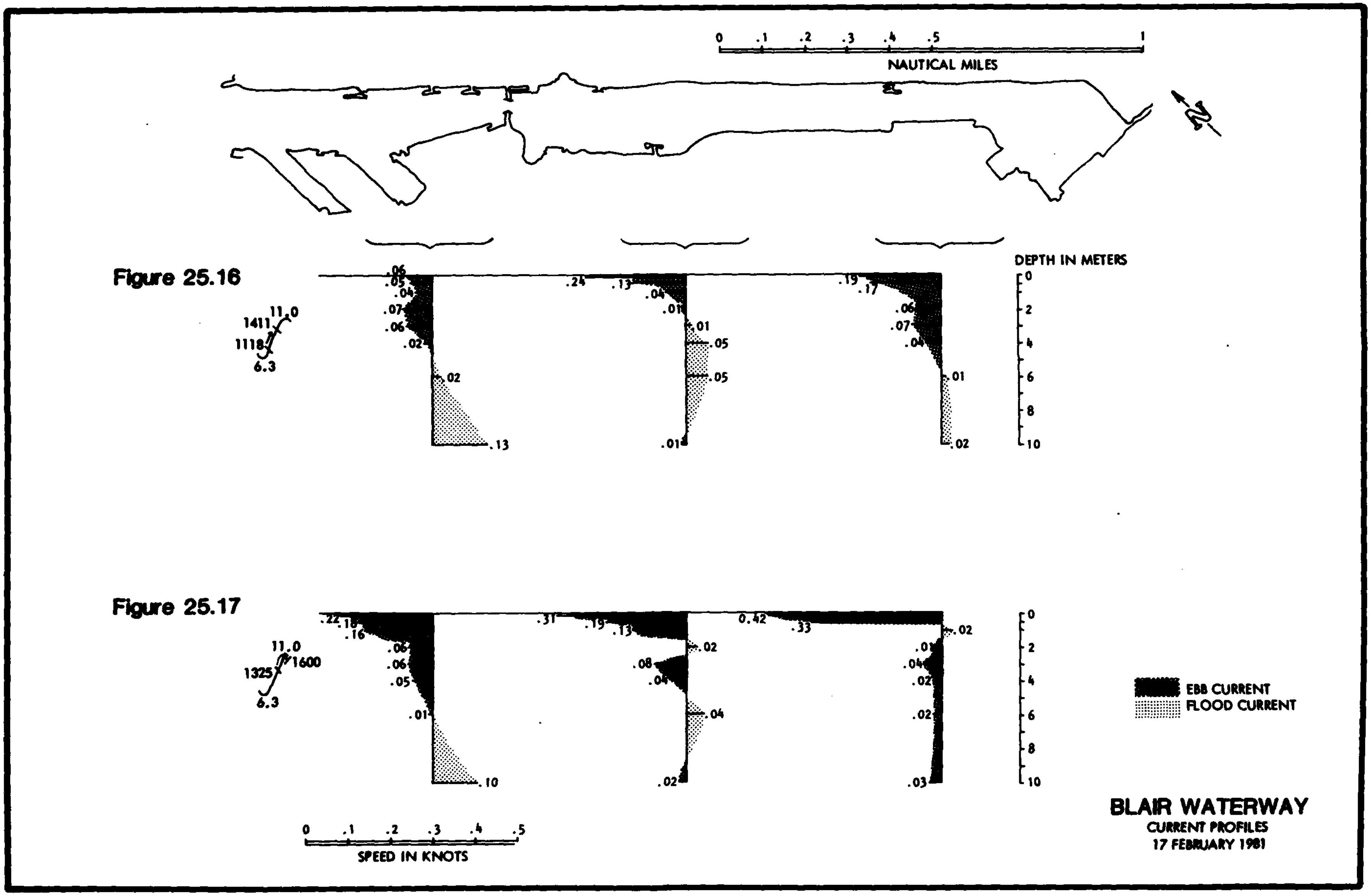
BLAIR WATERWAY WINTER STUDY 18 FEB 1981 OUTER SET 9

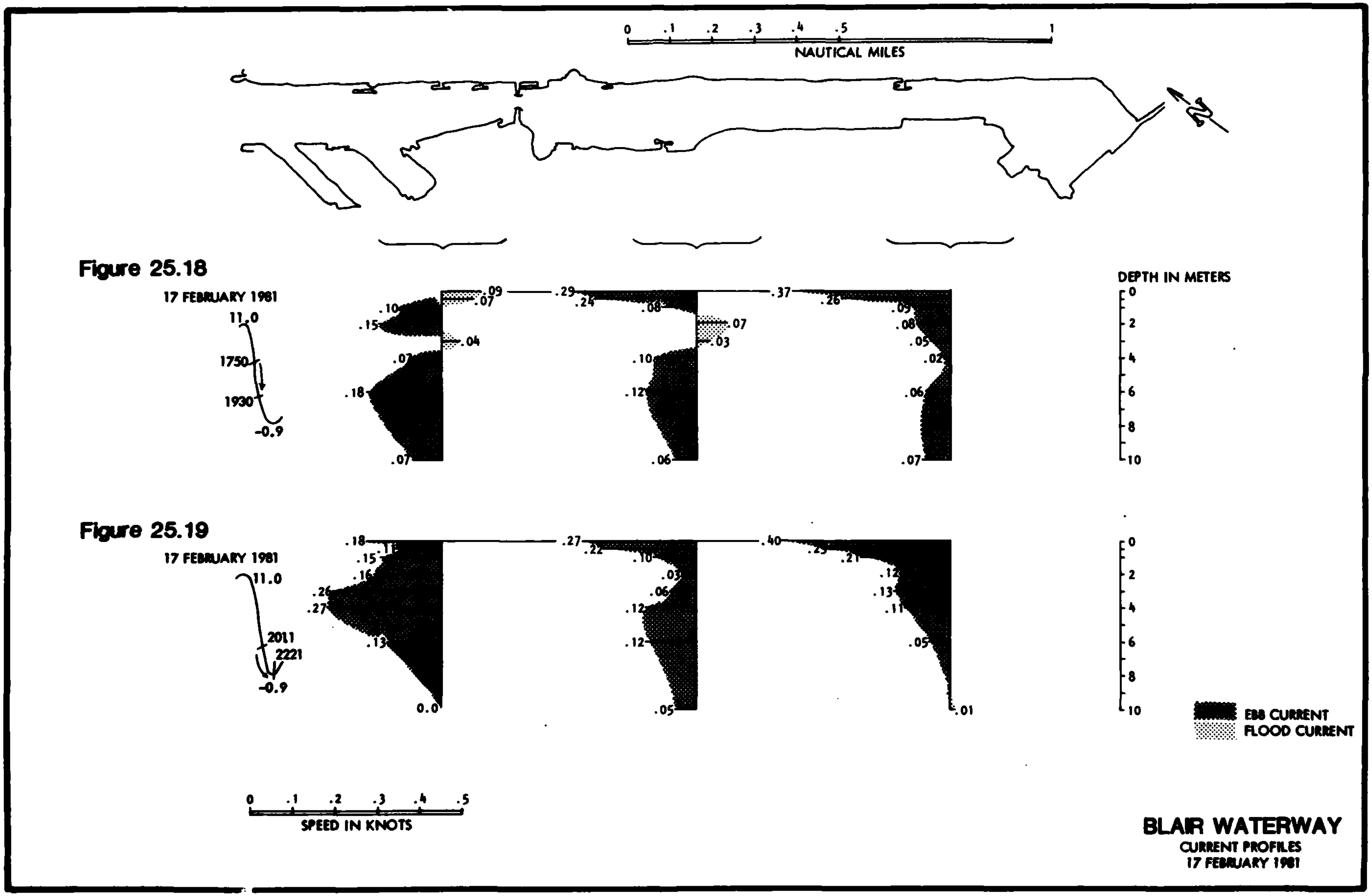
BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE - 112. MOVED 0.08 NMI IN 1.10 HRS. AVG SPD 0.08 KTS						
DEPTH - 10.0 M						
N	550	1155	47-16-28	122-24-22		
					0.04	140
N	563	1222	47-16-27	122-24-21		
					0.10	151
N	581	1301	47-16-24	122-24-18		
DROGUE - . MOVED 0.00 NMI IN 0.00 HRS. AVG SPD 0.00 KTS						
DEPTH - . M						
	0	0	0- 0- 0	0- 0- 0		
					1.36	13
N	563	1222	47-16-27	122-24-21		

TABLE 2.24-M

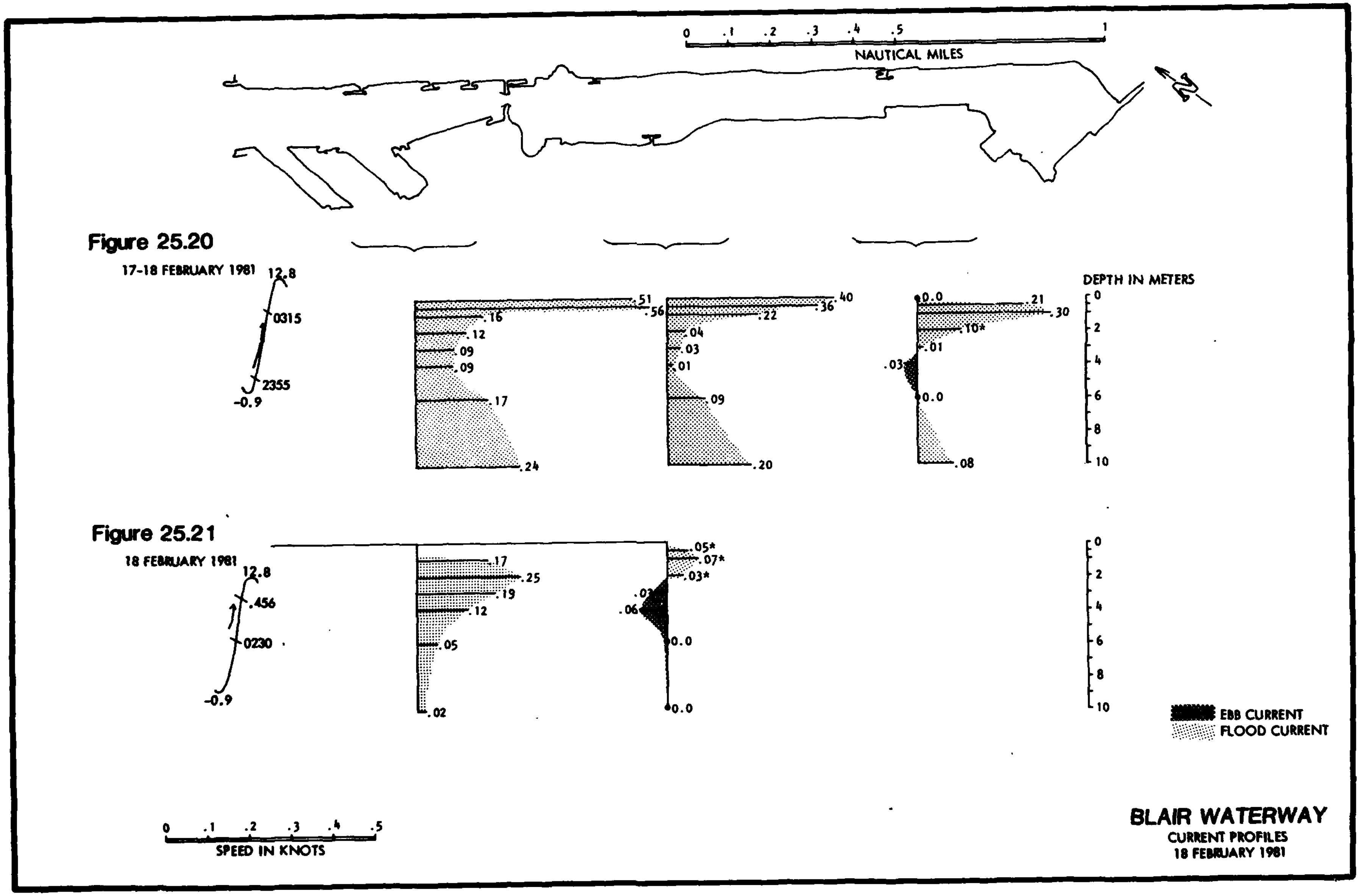
BLAIR WATERWAY WINTER STUDY 18 FEB 1981 MIDDLE SET 9

BOAT	FIX	TIME	LATITUDE	LONGITUDE	SPEED	DIR
DROGUE = 28. MOVED 0.02 NMI IN 0.43 HRS. AVG SPD 0.06 KTS DEPTH = 0.1 M						
N	551	1204	47-16- 2	122-23-41	0.06	110
N	568	1230	47-16- 2	122-23-39		
DROGUE = 27. MOVED 0.01 NMI IN 0.39 HRS. AVG SPD 0.04 KTS DEPTH = 0.5 M						
N	552	1204	47-16- 2	122-23-41	0.04	80
N	567	1228	47-16- 2	122-23-39		
DROGUE = 65. MOVED 0.03 NMI IN 0.46 HRS. AVG SPD 0.07 KTS DEPTH = 1.0 M						
N	553	1204	47-16- 2	122-23-41	0.07	211
N	572	1232	47-16- 0	122-23-43		
DROGUE = 73. MOVED 0.03 NMI IN 0.45 HRS. AVG SPD 0.07 KTS DEPTH = 2.0 M						
N	554	1204	47-16- 2	122-23-41	0.07	158
N	571	1231	47-16- 0	122-23-40		
DROGUE = 81. MOVED 0.05 NMI IN 0.45 HRS. AVG SPD 0.12 KTS DEPTH = 3.0 M						
N	555	1204	47-16- 2	122-23-41	0.12	139
N	570	1231	47-16- 0	122-23-38		
DROGUE = 92. MOVED 0.03 NMI IN 0.43 HRS. AVG SPD 0.08 KTS DEPTH = 4.0 M						
N	556	1204	47-16- 2	122-23-41	0.08	127
N	569	1230	47-16- 1	122-23-39		
DROGUE = 100. MOVED 0.01 NMI IN 0.48 HRS. AVG SPD 0.02 KTS DEPTH = 6.0 M						
N	557	1204	47-16- 2	122-23-41	0.02	226
N	574	1233	47-16- 2	122-23-42		
DROGUE = 113. MOVED 0.02 NMI IN 0.48 HRS. AVG SPD 0.05 KTS DEPTH = 10.0 M						
N	558	1204	47-16- 2	122-23-41	0.05	207
N	573	1233	47-16- 1	122-23-42		

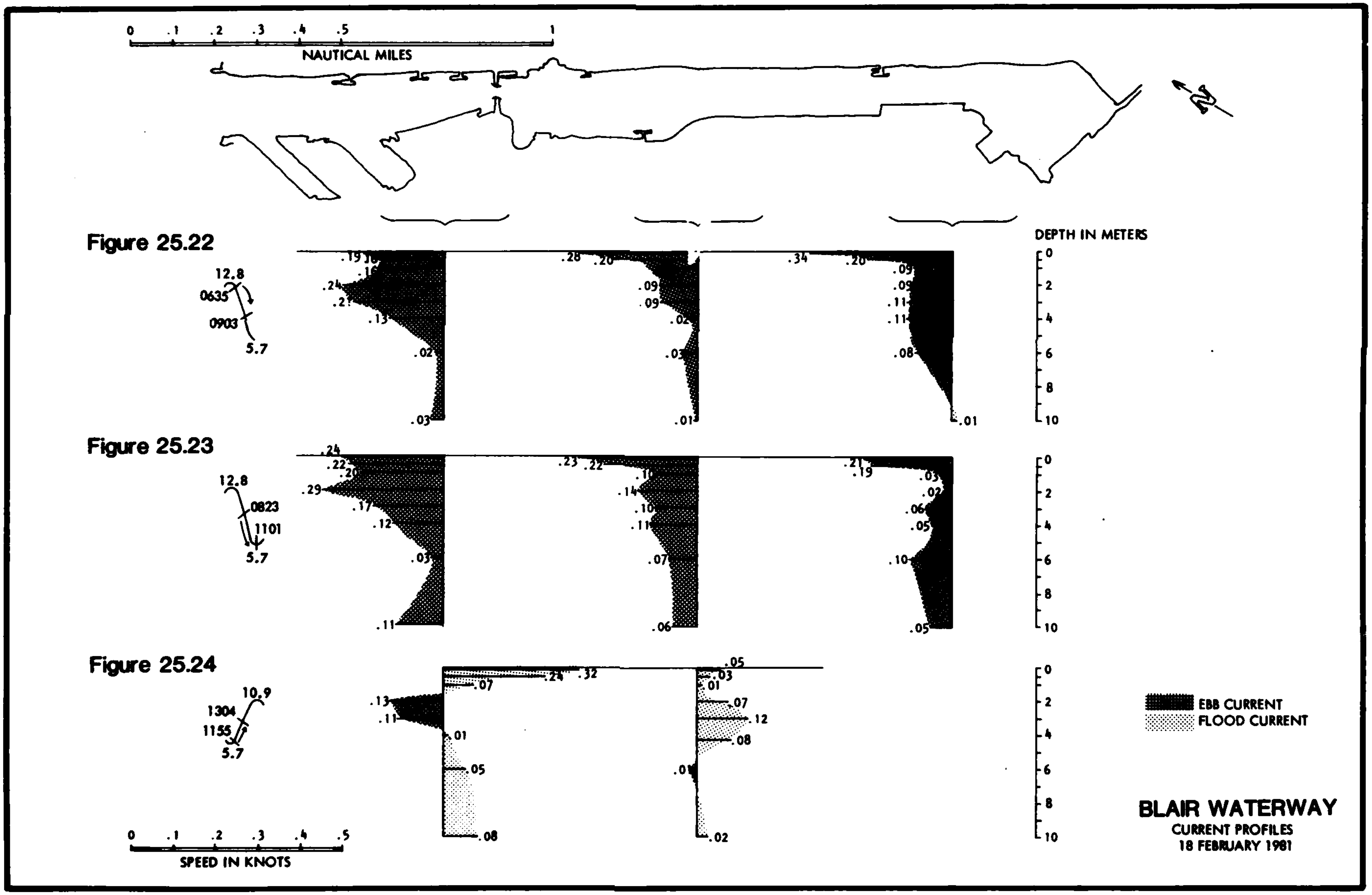

NAUTICAL MILES
0 .1 .2 .3 .4 .5 1
N
Figure 25.16
1411
1118
11.0
6.3
DEPTH IN METERS
0 2 4 6 8 10
Figure 25.17
1325
1600
11.0
6.3
EBB CURRENT
FLOOD CURRENT
SPEED IN KNOTS
0 .1 .2 .3 .4 .5
BLAIR WATERWAY
CURRENT PROFILES
17 FEBRUARY 1981



BLAIR WATERWAY
CURRENT PROFILES
17 FEBRUARY 1981



0 .1 .2 .3 .4 .5 1
NAUTICAL MILES
Figure 25.20
17-18 FEBRUARY 1981
12.8
0315
2355
-0.9
.51
.56
.16
.12
.09
.09
.17
.24
.40
.36
.22
.04
.03
.01
.09
.20
0.0
.21
.30
.10*
.01
.03
0.0
.08
DEPTH IN METERS
0 2 4 6 8 10
Figure 25.21
18 FEBRUARY 1981
12.8
.456
0230
-0.9
.17
.25
.19
.12
.05
.02
.05*
.07*
.03*
.03
.06
0.0
0.0
0 2 4 6 8 10
EBB CURRENT
FLOOD CURRENT
0 .1 .2 .3 .4 .5
SPEED IN KNOTS
BLAIR WATERWAY
CURRENT PROFILES
18 FEBRUARY 1981



NAUTICAL MILES
0 .1 .2 .3 .4 .5 1
Figure 25.22
12.8
0635
0903
5.7
Figure 25.23
12.8
0823
1101
5.7
Figure 25.24
10.9
1304
1155
5.7
DEPTH IN METERS
0 2 4 6 8 10
EBB CURRENT
FLOOD CURRENT
SPEED IN KNOTS
0 .1 .2 .3 .4 .5
BLAIR WATERWAY
CURRENT PROFILES
18 FEBRUARY 1981